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United States Coast Guard Integrated Risk Assessment Process

Volume I

FINAL REPORT
SEPTEMBER 1998

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16. Abstract

Due to the new challenges (e.g., government downsizing, increased system complexity, ever-changing high-risk operations) faced by the Coast Guard, the Coast Guard Research and Development Center (RDC) was requested to explore the possibility of applying system safety concepts, including the use of risk analysis and enhancement of inspection procedures, to improve Coast Guard operations and facility safety. The Coast Guard RDC teamed with JBF Associates, Inc. (JBFA), a consulting firm specializing in hazard and risk analysis/management, to develop a risk-based loss prevention program. The initial focus was on developing one portion of the risk-based loss prevention program, a risk assessment process. This report discusses the development, validation, and end product (the Integrated Risk Assessment [IRA] process) of this effort. Effective implementation of the IRA process provides the Coast Guard with risk-based information for: 1) controlling and reducing loss exposure, (2) making risk-based decisions, and (3) using limited resources more efficiently. The IRA process proved to be an effective and efficient risk assessment tool for various types of vessels and their operations, as well as shore facilities and their operations.

This report contains three volumes. Volume I consists of the main text of the report and Attachment A: Integrated Risk Assessment (IRA) Manual. Volume II consists of Attachment B: Coarse Hazard Analysis of a WMEC-210 Vessel in Support of the Paragon Project and Attachment C: Coarse Hazard Analysis of the Integrated Support Command (ISC) at Seattle, WA. Volume III consists of Attachment D: Detailed Hazard Analysis of WMEC-270 Small Boat Operations, Attachment E: Detailed Hazard Analysis of WLIC-160 Deck Operations, and Attachment F: Risk-based Safety Survey of a WHEC-378 Vessel.

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EXECUTIVE SUMMARY

Integrated Risk Assessment (IRA) Program

This report describes the efforts within the Loss Exposure and Risk Methodology (LERAM) project during 1996-1997 to develop a forward-looking loss system for the U.S. Coast Guard. The IRA program integrates risk assessment and traditional safety survey activities to identify, characterize, and monitor hazards and safeguards from a risk prioritization perspective. In addition, the IRA provides the risk characterization information needed for risk management activities that are currently being developed and integrated into existing Coast Guard management practices. Risk characterization information is obtained from a variety of data sources and subject matter expert (Coast Guard operations and maintenance personnel) assessments facilitated by trained assessment facilitators (Coast Guard health and safety staffs).

The IRA program is a systematic, predictive approach for characterizing risks associated with operational and maintenance activities and preventing potential losses. The program approach is to characterize total risk to a Coast Guard unit or facility. Characterizing how inherent hazards can produce losses, assessing the types/levels of safeguards needed, developing recommendations for reducing risks, and generating risk profiles for operations/facilities enables Coast Guard leadership to effectively manage risk. Possibly, just as important, since operational personnel characterize the hazard and safeguard interplay involved with accident scenarios, their understanding, awareness, will lead to personal risk reduction measures.

Risk information is used to assist in assessing the significance and importance of safeguards for preventing or mitigating losses. Safeguards can be ranked based on their contribution to the overall risk and monitored appropriately. Understanding safeguard contributions to risk enables the scope and number of safety surveys to be modified to more effectively employ trained safety professionals. In addition, characterizing the effectiveness of safeguards provides valuable information to correct, modify, or eliminate safeguards to reduce risk and reduce maintenance and monitoring resources.

The Coast Guard Integrated Risk Assessment (IRA) Program addresses risks from the perspective deemed most appropriate by Coast Guard operations, maintenance, health and safety, and program personnel. Industry accepted techniques, definition, and measures of success were used as the basis for a process that provides the Coast Guard with the means necessary to

effectively identify, assess, and manage risk. It is a scientific, predictive approach, based on both historical information and expert judgment.

The Integrated Risk Assessment program consists of a both coarse and detailed risk analysis processes, the integration of risk assessment into our established safety survey practice, and necessary training, techniques, and tools. The critical management systems necessary to support such a program and ensure its integration into other critical business practices are currently under development. The Coast Guard's risk management program while being incrementally developed and fielded will completely transition from the research and development phase by the year 2001.

As with industry and other government agencies, the Coast Guard expects risk assessment/ management methods to be continuously revised to account for different types of loss exposures, new technologies that affect data, analysis, documentation, and communication of the results, and changing requirements.

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List of Acronyms and Abbreviations

ATON	Aids to Navigation
ESU	Electronic Support Unit
FMEA	Failure Mode and Effects Analysis
HAZOP	Hazard and Operability Analysis
IRA	Integrated Risk Assessment
ISA	Integrated Safety Assessment
ISC	Integrated Support Command
LERAM	Loss Exposure and Risk Analysis Methodology
MLC-LANT	Maintenance Logistics Command, Atlantic
MLC-PAC	Maintenance Logistics Command, Pacific
MSO	Marine Safety Office
NESU	Naval Engineering Support Unit
RDC	U.S. Coast Guard Research and Development Center
RIN	Risk Index Number
WHEC	High Endurance Cutter
WISE	Worker and Instruction Safety Evaluation Analysis
WMEC	Medium Endurance Cutter
WLIC	Construction Tender

1. Introduction

As part of the United States Coast Guard's (Coast Guard's) Safety Program, the Research and Development Center (RDC) was requested to explore the possibility of applying system safety concepts, including the use of risk analysis and the enhancement of the safety survey process with risk-based information, to improve Coast Guard operations and facility safety. This research was executed under the Coast Guard Loss Exposure and Risk Analysis Methodology (LERAM) project. The Coast Guard RDC teamed with JBF Associates, Inc. (JBFA), a consulting firm specializing in hazard and risk analysis/management, to develop a risk-based loss prevention program consisting of a risk assessment methodology (techniques and tools) and a risk management program. This report documents the development of the risk assessment methodology and presents the methodology.

Development of the methodology began in 1995 with the following objectives:

- Develop practical approaches for estimating risk exposure for various Coast Guard activities so that managers can use the risk-based information in decision making
- Identify/develop efficient and effective risk analysis approaches for providing the information that Coast Guard personnel will need for decision making
- Demonstrate the effectiveness of the selected risk analysis approaches
- Enhance the Coast Guard safety survey process to make it more efficient and effective by focusing on significant risks and reducing emphasis on unnecessary requirements
- Integrate risk analysis and safety surveys to provide reliable measures of risk exposure associated with Coast Guard missions

The result of achieving these objectives is the Integrated Risk Assessment (IRA) process. The IRA process provides the Coast Guard with the means necessary to effectively manage and control risk at its units (both vessels and shore facilities). The process supplies risk-based information to aid Coast Guard personnel in making tactical as well as long-term strategic decisions. It is a systematic, predictive approach (based on both historical information and expert judgment) for understanding the risk associated with Coast Guard activities and preventing potential losses within the Coast Guard by:

- Identifying how inherent hazards associated with Coast Guard operations/facilities can produce potential losses

- Characterizing the risks of potential losses

- Assessing the types/levels of safeguards needed to effectively manage the identified risks

- Helping to ensure that safeguards adopted by the Coast Guard are effectively implemented in the field

- Developing recommendations for reducing risks (i.e., better safeguards for operations/ facilities)

- Producing risk profiles for operations/facilities that Coast Guard managers can use to manage Coast Guard risks

As shown in Figure 1.1, the IRA process has two distinct, yet closely related, parts: (1) risk analysis process (which is divided into coarse risk analysis and detailed risk analysis) and (2) risk-based safety survey process.

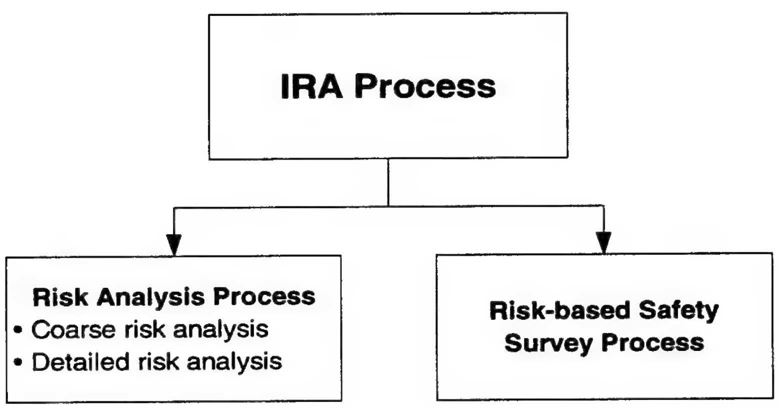


Figure 1.1 IRA Process

Coarse risk analysis is a team-oriented, high-level (coarse), predictive analysis tool for identifying hazards, potential mishaps (losses), safeguards, risk associated with the mishaps, and recommendations for reducing risk. The coarse risk analysis tool is designed to be performed by Coast Guard safety professionals who have received modest risk assessment training.

Detailed risk analysis is a collection of standard, industry-proven, predictive analysis tools that can be used when specific results with a higher degree of resolution and/or certainty are required. The detailed risk analysis tools require an experienced analyst.

The risk-based safety survey process is a process for systematically ensuring that the safeguards designed to control risk are being effectively implemented in the field. The process uses risk-based information to reduce the total resources required to effectively control overall risk by focusing those resources on the issues associated with the most significant risks. It includes a combination of field observations of equipment status as well as direct reviews of management programs/documentation. This highlights where safeguard implementation weaknesses are increasing risks. The risk-based safety survey process also includes methods for determining the root causes of deficiencies. The process may be performed by Coast Guard safety professionals or even unit safety supervisors who have modest training.

The remainder of this report is divided into six sections. Section 2 (Background) discusses (1) the circumstances that have led the Coast Guard to explore the development of a risk assessment process, (2) risk fundamentals, and (3) the purpose and benefits of a risk assessment process. Section 3 (Guiding Principles) discusses the 10 principles the RDC and JBFA followed during the development of a Coast Guard risk assessment process. Next, Section 4 (IRA Process Description) familiarizes the reader with the final results of the Coast Guard risk assessment process development by providing a brief explanation of the various parts of the IRA process. The approach used to develop the IRA process, as well as the results of validating the process, are discussed in Section 5 (IRA Process Development). A discussion of future work that will focus on Coast Guard risk management systems is included in Section 6 (Future Development). Section 7 (Concluding Remarks) contains final thoughts about the IRA process. The attachments to this report include the *IRA Manual* (which fully documents the IRA process) and example applications of the IRA process on vessel and shore assets

Note: During the course of this research project, the term "hazard analysis" was changed to "risk analysis" to better describe the process. Therefore, the term "hazard analysis" will be found in many previous letters, reports, and other work products related to this project. These previous references to hazard analysis should now be interpreted as references to risk analysis.

2. Background

History of Risk Assessment

Modern risk assessment has roots in probability theory and scientific methods for identifying causal links between adverse health effects and different types of hazardous activities. In 1792, Pierre Simon de LaPlace demonstrated a modern quantitative risk assessment by calculating the probability of death associated with and without receiving the smallpox vaccination. Insurance may be one of the oldest strategies for dealing with risk. In 1950 B.C., the Code of Hamurabi formalized bottomry contracts containing a risk premium for the chance of loss of ships and cargo and in 1583 the first life insurance policy was issued in London.

Risk mitigation measures in the form of water and garbage sanitation in the 19th and 20th centuries were extremely successful in decreasing the risk of mortality and morbidity. Along similar lines, building and fire codes, boiler testing and inspection, and safety engineering on steamboats, railroads and automobiles greatly contributed to public safety. A whole field of risk management was developed based on common sense risk analysis, which increased the longevity and generally improved the quality of life for most citizens in industrialized countries.

Conceptual development of modern risk analysis in the United States and other industrially developed countries rose from the potentially catastrophic consequences and uncertainty associated with high hazard industries such as nuclear power, chemical processing, aviation, and modern weapon systems. In addition, increased awareness and demand for public safety in industrialized environments led governments to establish agencies similar to our Environmental Protection Agency, Occupational Safety and Health Administration, and the National Institute for Occupational Safety and Health.

Evolution

Formal risk assessment studies initially focused on the potential causes and consequences of major events that could involve large numbers of injuries or economic impact, such as explosions and release of toxic substances. Typically, a risk assessment focused on ways that equipment failures, software problems, human errors, and external factors (e.g., weather) contributed to losses. Risk assessments typically did not include industrial health and safety issues, although these can significantly contribute to the total losses experienced by an organization.

These initial assessment techniques are characterized by a strong emphasis on quantitative information. This initial emphasis continues to have a strong influence on the thinking of many risk management practitioners, in that qualitative assessments involve human judgement, thus are inherently unreliable or inaccurate. These initial techniques were designed to scientifically address all aspects of complex systems and facilitate analysis and what-if scenarios to be considered independent of human analysis.

As experience was gained in the field of risk assessment, and more industries began to see the benefits of assessing loss exposure, less expensive and more robust methods were needed to offset the expertise and data requirement demands of strictly quantitative techniques. Semi-quantitative techniques were developed to incorporate subject matter expertise with hard data.

As engineered systems became more reliable and accident scenario and risk contribution awareness grew, emphasis began shifting toward human performance and management systems. These contributors had the potential to effect a wide variety of loss scenarios and their failure rates were not well understood.

Perspective

There are a variety of ways to describe risk and many definitions are products of established manufacturing and health industries. Chemicals risks, for example, are traditionally viewed in terms of acute toxicity, subchronic and chroinc toxity, cancer potency, dose vs. response, and exposure. Chemical risk assessments often address the establishment of concentrations that could be tolerated by most people without adverse health effects. Environmental awareness has broadened the perspective of chemical risk assessment to include impacts to the environment that may or may not impact public health.

Coast Guard Safety Experience

The Coast Guard, like many organizations, adheres to a traditional safety program emphasizing prescriptive codes, mishap (loss or accident) reporting, and incident investigations. The basic risk analysis tools that the Coast Guard has traditionally relied upon are the warning flags obtained from reported mishaps, single significant events, hazardous condition notifications, and periodic safety audits. Anomalies in mishap trends, significant losses, anomalous safety audit findings, and reported hazards are benchmarked against the Coast Guard "corporate experience."

Over time, the Coast Guard has made a series of improvements to the mishap reporting procedures to provide greater resolution of the factors involved in losses and to help ensure consistently accurate reporting. The organization has strived to address such issues as human errors, the importance of root causes, the importance of management's risk acceptance level, and the shortcomings of electronic databases.

The Coast Guard realized that government downsizing, rapidly changing technologies, increased system complexities, rising construction and repair costs, high turnover rates, and ever-changing high-risk operations may erode the low incident rate and good safety record of its traditional safety program. To address these new challenges, the Coast Guard decided to make a concerted effort to understand and apply industry-proven loss prevention and risk management practices to its operations and facilities. This effort involves developing a risk-based loss prevention program for the Coast Guard, which includes risk assessment techniques and tools under the umbrella of an overall risk management program.

The Coast Guard initially focused on developing risk assessment techniques and tools (the topic of this report). Before going any further, it is advantageous to briefly discuss risk, risk assessment, and risk management.

Risk is defined as the combination of the expected frequency and consequence of losses that could occur as a result of an activity. Understanding risk includes addressing the following three questions:

- What can go wrong?
- How likely is it?
- What are the impacts?

Therefore, analyzing risk involves identifying losses of interest (What can go wrong?), estimating the frequency of occurrence (How likely is it?), and evaluating the potential consequences (What are the impacts?).

Risk cannot be completely eliminated; however, it can be managed. Many risks are accepted as a cost of doing business. In controlling losses, it is important to (1) understand the associated risks, (2) understand the means used to control the risks, (3) understand the level of acceptable risk (accepted cost of doing business), and (4) identify and manage safeguards to reduce unacceptable risk.

Risk assessment is the systematic process of identifying potential losses and characterizing the frequencies and severities of those losses. This process focuses on understanding loss exposure based on existing conditions/protections (safeguards) as well as generating recommendations for additional safeguards as appropriate.

Risk management is the use of Coast Guard management policies, procedures, and practices (management systems) to control Coast Guard risks. Figure 2.1 shows the relationship between risk management with risk assessment (IRA process) and Coast Guard management systems used to control risk. (Attachment A, Sections 1 through 3, contain more detailed information on risk, risk assessment, and risk management.)

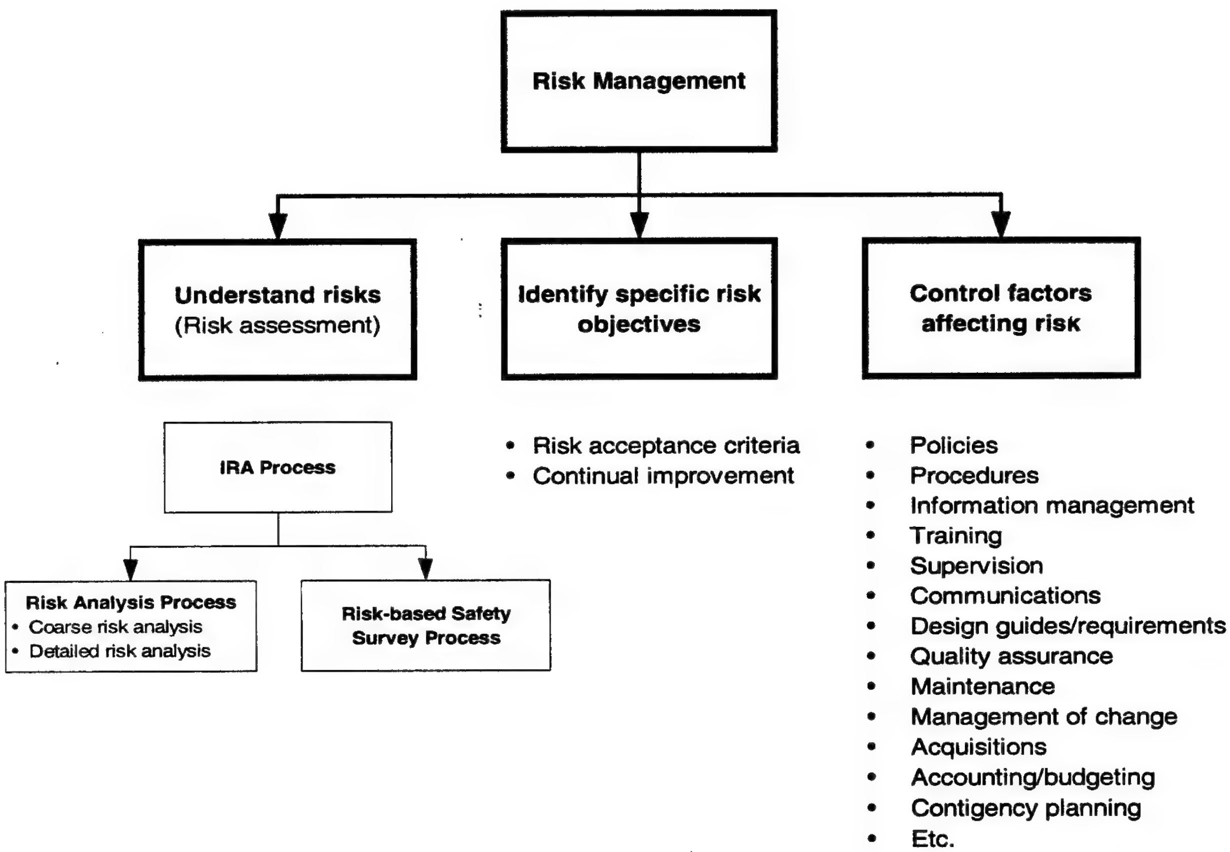


Figure 2.1 Risk Management

In general, there are two approaches to managing risk. One could be called the fly-fix-fly approach. This technique of not taking action until an accident occurs has been proven to be quite costly in terms of personnel injuries, property damage, and environmental consequences.

The second approach could be called the proactive approach. This approach, with risk assessment as a cornerstone, allows management the opportunity to eliminate or reduce risks to an acceptable level before losses occur.

While the Coast Guard is encouraged to operate with fewer and fewer resources (both equipment and personnel), more emphasis is placed on controlling losses and reducing loss exposure. The Coast Guard cannot afford to operate under a fly-fix-fly philosophy. It recognizes the advantages of developing measures to understand how losses occur, and it is committed to designing and maintaining safeguards (e.g., policies, procedures, systems, equipment) to prevent these losses from occurring (a proactive approach to loss prevention).

A risk assessment methodology is a proactive tool used for controlling losses and reducing loss exposure. The risk-based information from a risk assessment process (1) provides decision makers with the ability to focus resources in the most effective and efficient manner to reduce losses and (2) helps them make strategic and operational decisions that reduce loss exposure (e.g.: Can the operation be performed safely in these conditions? Should equipment A or B be purchased? Should equipment C be maintained more often than equipment D?). The RDC and JBFA developed the IRA process (risk analysis process and risk-based safety survey process) to fulfill the Coast Guard's risk assessment needs.

Table 2.1 shows two perspectives on Coast Guard risk management. One is Coast Guard risk management from a historical perspective (before). The other perspective is Coast Guard risk management after implementation of the IRA process (after). The table includes the approach for achieving risk understanding and risk control and the cost and effectiveness of risk management.

Table 2.1 Comparison of Risk Management Perspectives

	Risk Understanding Approach	Risk Control Approach	Risk Management Effectiveness	Cost to the Coast Guard
Before	**Historical** • using past mishap information for addressing potential losses	**Reactive** • historical event focus • fly-fix-fly	• manages historically repeated events • will not adequately predict and prevent losses that have not occurred previously or identify and correct root causes • no risk prioritization to direct management of safeguards • higher loss exposure due to changes from historical operations and uncorrected root causes	**High** • significant effort for collection and management of information related to safeguard management • must ensure all safeguards (regardless of associated risk) are maintained at the same level • losses due to recurring losses and uncorrected root causes
After	**Predictive** • using historical information and expert judgment to predict potential losses	**Proactive** • predicted event focus • root cause focus • based on historical information as well as expert judgment	• manages both historical events and other future high risk events • identifies and corrects root causes • prioritizes safeguards to reduce resources required for safeguard management • lower loss exposure due to proactive loss prevention	**Moderate** • risk analysis requires higher initial setup cost • focused information collection and safeguard management based on risk-based prioritization of safeguards • reduced cost of losses due to a proactive loss prevention approach and the elimination of root causes

3. Guiding Principles

To develop the risk assessment process (the IRA process), the RDC and JBFA followed 10 guiding principles. They are as follows:

(1) **Consistent with Coast Guard culture** — The risk assessment process must be consistent with the Coast Guard management style, data-keeping strategies, and internal/external regulatory requirements.

(2) **Generically applicable to all types of Coast Guard operations and facilities** — The process must be capable of assessing various types of vessels and their operations as well as shore facilities and their operations.

(3) **Flexible enough not to overwork or underwork an issue** — The process must be capable of assessing an issue at the appropriate level of detail required to provide adequate results for Coast Guard decision making.

(4) **Practical for Coast Guard personnel to implement** — The process should not be unnecessarily complicated. Coast Guard personnel who have moderate risk analysis training should be capable of successfully using the process.

(5) **Designed to make maximum use of existing Coast Guard processes and information** — The process should not "re-invent the wheel." Existing Coast Guard processes and information should be integrated into the risk assessment process where appropriate.

(6) **Based on solid risk assessment fundamentals** — The foundation for the process should be built on solid risk assessment fundamentals that have been proven over time across a variety of applications.

(7) **Based on predictive reasoning techniques as well as historical perspective techniques** — The process must be capable of identifying the means by which losses occur (before they occur) and provide the Coast Guard with information that will allow it to implement measures to prevent these losses from occurring. The process must also take advantage of past mishap information to help the Coast Guard control future losses.

(8) **Useful to all branches of the Coast Guard in their decision making** — The process

should produce results that are easily understood and are useful to all levels of Coast Guard management.

(9) **Focused on eliminating root causes of problems, not just symptoms** — The process should identify root causes of deficiencies and losses and provide the Coast Guard with the information necessary to prevent these root causes.

(10) **Useful in focusing Coast Guard analysis, prevention, and corrective action resources on the most significant risks** — The risk-based information produced by the process should help the Coast Guard efficiently and effectively allocate its limited resources in reducing loss exposure.

Following these guiding principles when developing the IRA process produced efficient and effective risk assessment techniques/tools for the Coast Guard.

4. IRA Process Description

The IRA process consists of two subprocesses: (1) risk analysis and (2) risk-based safety survey. Figure 4.1 is a representation of the IRA process. Ellipses such as "Coast Guard loss experience" are types of information used in the risk analysis and risk-based safety survey processes. Hexagons such as "Risk profiles" are types of information these processes provide to Coast Guard management for risk-based decision making.

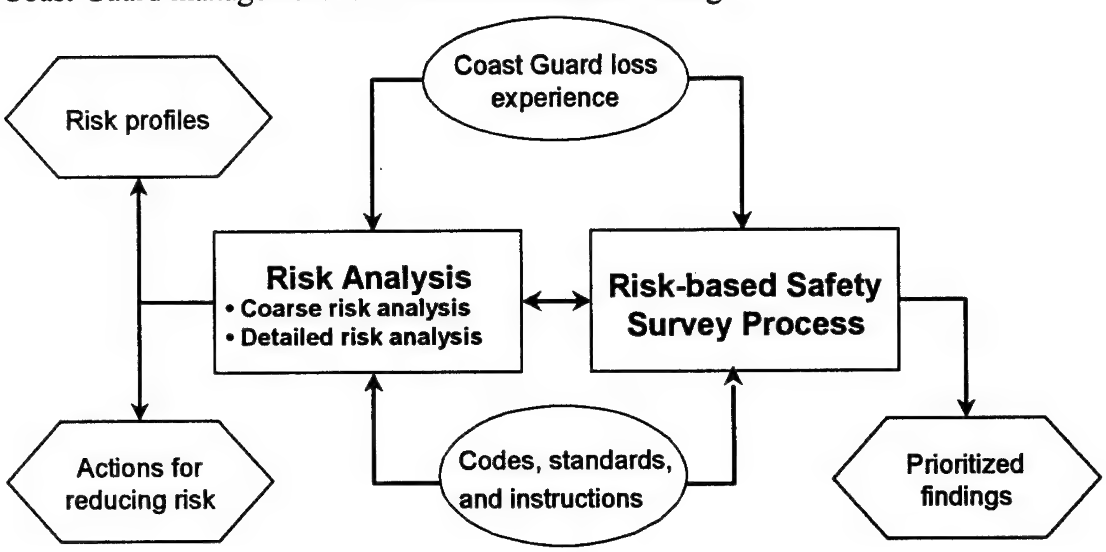


Figure 4.1 Integrated Risk Assessment (IRA) Process

This section briefly discusses the main elements of the IRA process and the steps involved in performing the process. Sections 4 through 8 of Attachment A, *Integrated Risk Assessment (IRA) Manual*, provide a more detailed description of the process as well as the detailed steps for performing the process.

4.1 Risk Analysis Process

The objectives for performing risk analyses include:

- Fewer losses over the life of platforms/facilities
- Reduced consequences when losses occur
- Improved training and understanding of system interactions and the effect of the human element
- More efficient and productive mission execution

A risk analysis involves:

- Identifying hazards systematically
- Postulating combinations of equipment failures/human errors/external events that allow the hazards to cause losses
- Characterizing the risks of the potential losses
- Identifying the most significant contributors to risk
- Providing summaries of risks (profiles) associated with various platforms/operations/functions
- Developing effective recommendations for better management of the known risks

The risk analysis process of the IRA process includes a set of tools (coarse and detailed risk analyses) for performing different types of hazard/risk analysis at various levels of detail.

4.1.1 Coarse Risk Analysis

Coarse risk analysis is the cornerstone and workhorse of the risk analysis methodology for the Coast Guard. It is designed to be performed by Coast Guard personnel and to satisfy most of the Coast Guard's needs for hazard/risk information in a practical and efficient manner. This method provides all of the types of results of more detailed evaluations, but with a lower degree of resolution. The coarse risk analysis methodology was developed from the hazard and

operability analysis technique used by the petrochemical industry. The methodology uses a team approach for postulating upsets to normal operations that could lead to undesirable consequences. The following are characteristics of a coarse risk analysis:

- Generally applicable to all types of Coast Guard platforms
- Capable of satisfying 60% to 90% of the Coast Guard's hazard/risk analysis needs without requiring the use of more detailed techniques
- Streamlined enough for efficient application without requiring extremely extensive evaluations
- Can be used by Coast Guard personnel who have modest risk analysis experience
- Built on solid hazard evaluation fundamentals that use not only historical perspective but also predictive reasoning

4.1.1.1 Coarse Risk Analysis Steps

Before discussing the steps of the coarse risk analysis, here are some definitions of terms that are important in understanding the steps of the analysis:

Operation/evolution — a specific operation performed in support of a Coast Guard mission (e.g., boarding a vessel)

Function — a distinct activity that supports one or more operations/evolutions (e.g., operating vessels/craft)

Deviation — an off-normal condition or situation that has the potential to result in a mishap (loss)
(e.g., incorrect position/direction/speed)

There are five major steps in performing a coarse risk analysis:

(1) **Determine the scope of the coarse risk analysis** — This step includes determining the equipment, system, unit, etc., to be analyzed. More specifically, it identifies the operations/evolutions and functions of the Coast Guard unit to be considered in the analysis.

(2) **Screen low risk operations/evolutions, functions, deviations, and locations** — In this step, the operations/evolutions and functions are reviewed at a high level to eliminate lower risk issues from further analysis.

(3) **Analyze deviations** — Analyzing deviations includes identifying causes, mishaps (losses), and safeguards applicable to each deviation within the scope of the analysis. This step also includes estimating risk associated with deviations and developing recommendations for reducing risk.

(4) **Generate a risk profile** — This step involves using the data collected in Step 3 to characterize the risk for the Coast Guard unit being analyzed. Some examples of these characterizations are presented in the next section.

(5) **Evaluate the benefit of risk reduction recommendations** — Step 5 determines the benefit of implementing the risk reduction recommendations developed during the analysis. Information from this step helps Coast Guard managers decide which recommendations to implement and in what order.

These steps are discussed in significant detail in Section 5 of Attachment A. The current set of operations/evolutions, functions, and deviations for vessels and shore facilities can be found in Section 9 of Attachment A.

4.1.1.2 Coarse Risk Analysis Results

The coarse risk analysis produces various results that enable Coast Guard personnel to make risk-based decisions and improve the management of risks associated with Coast Guard missions. Below is a sample of the types of risk-based management information available from the coarse risk analysis. Section 5 of Attachment A contains detailed instructions for obtaining these results and additional results that can be obtained from this technique. Attachments B and C provide an example of a coarse risk analysis for a Coast Guard vessel and shore facility, respectively.

An example of the data collected during a coarse risk analysis is shown in Figure 4.2. These results document the potential loss (mishap) scenarios associated with specific operations/evolutions and functions. These scenarios are based on possible deviations that may occur. Included are characterizations of the risk associated with the scenario using a combination

of frequency categories and mishap severity levels to estimate risk as a dollar/year loss considering potential safety, economic, mission, and environmental losses. Risk is expressed as a risk index number (RIN), which is the dollar/year loss divided by 10,000. RIN is calculated by using an average mishap cost and the lower bounds of the estimated frequency range of occurrence. The risk (dollar/year loss) is shown within parentheses under the RIN. Finally, a certainty estimate is assigned to the risk characterization.

Coarse Risk Analysis									
Operation/Evolution: Working aids to navigation									
Function: Operating lifting equipment									
			Frequency						
Deviation	Causes	Mishaps	A/B	C	D	RIN† (Risk*)	Certainty	Safeguards	Recommendations
1.1 Loss of support	Crane cable/ rigging failure Loss of power to the crane Structural failure in buoy during lifting	Equipment damage/loss Hazardous exposure: contact injury (dropped objects, broken lines, etc.)	2	4	5	0.063 ($630)	High	Boom is inspected annually Crew inspects crane daily and cable annually	Consider a formal preventive maintenance program for crane rigging and hardware Consider further investigation of the same, particularly during loss of power

† Risk Index Number
* Estimated dollar/year loss considering safety, economic, mission, and environmental losses.

Figure 4.2 Identification of Hazards and Their Associated Risk

Figure 4.3 shows the number of loss scenarios (deviations) that are estimated to occur at a certain frequency and result in a certain magnitude of loss (class of mishap). The frequency is represented by a frequency category. For example, for the Class C mishap category in Figure 4.3, fifteen different deviations are considered Probable (Frequency Category 4). This risk profile is developed from the risk information collected during the coarse risk analysis (as shown in Figure 4.2).

Frequency Categories	Class of Mishap A/B	Class of Mishap C	Class of Mishap D
Continuous (8)	0	0	0
Very Frequent (7)	0	2	2
Frequent (6)	0	5	5
Occasional (5)	1	9	9
Probable (4)	2	15	22
Improbable (3)	6	14	14
Rare (2)	11	17	10
Remote (1)	36	20	3
Incredible (0)	9	4	0

Figure 4.3 Risk Matrix Characterizing a Coast Guard Unit

A risk histogram of the operations/evolutions of a vessel is shown in Figure 4.4. The risk contribution or contribution of the operation/evolution to overall vessel risk is presented. This information can be used to identify the higher risk operations/evolutions. Similar histograms are typically developed for functions, types of deviations, types of mishaps (losses), locations, etc. A category with a low risk level may be an indication of the safeguard levels designed to eliminate or mitigate the risk of an inherently dangerous operation/evolution and not just relatively safe operation or evolution.

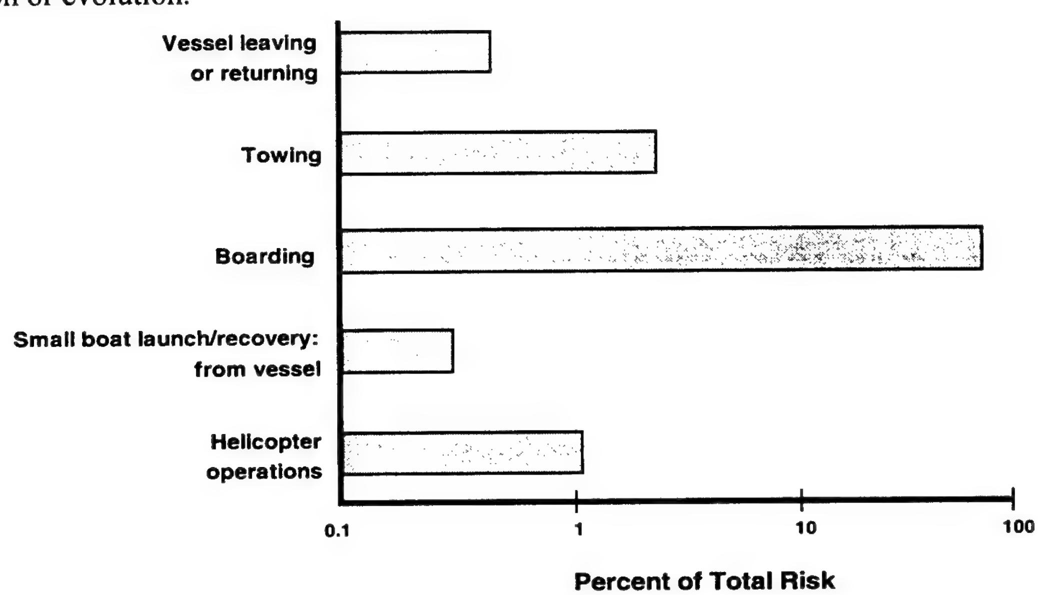


Figure 4.4 Percentage of Total Risk of Operations/Evolutions

Figure 4.5 displays an estimated frequency range of mishaps (losses) per year and expected number of mishaps over 50 years for a typical vessel in a vessel class. The table also includes the estimated frequency for mishaps for the entire vessel class.

Vessel Class	Typical Vessel Frequency Bounds for Mishaps (per year)			Typical Vessel Expected Number of Occurrences over 50 Years			Vessel Class Frequency Bounds for Mishaps (per year)		
	A/B	C	D	A/B	C	D	A/B	C	D
Vessel Class 1	0.13 to 1.3	1.4 to 14	26 to 261	7 to 65	70 to 700	1300 to 13000	1.3 to 13	14 to 140	261 to 2610
Vessel Class 2	0.002 to 0.03	0.2 to 2	7 to 70	10% chance to 2	10 to 100	350 to 3500	0.014 to 0.21	1.4 to 14	49 to 490

Figure 4.5 Range of Mishap Frequencies for Assets

Table 4.1 shows two example recommendations developed by a coarse risk analysis team and the estimated change in RIN of associated coarse risk analysis deviations if the recommendations are implemented. Change in RIN is determined by estimating changes to the risk characterizations (See Figure 4.2). Shown within parentheses under the RIN is risk expressed as dollar/year loss. A positive number represents savings due to implementation of the recommendation. A negative number represents loss due to implementation. Change in RIN is also used to produce results such as those in Figure 4.6.

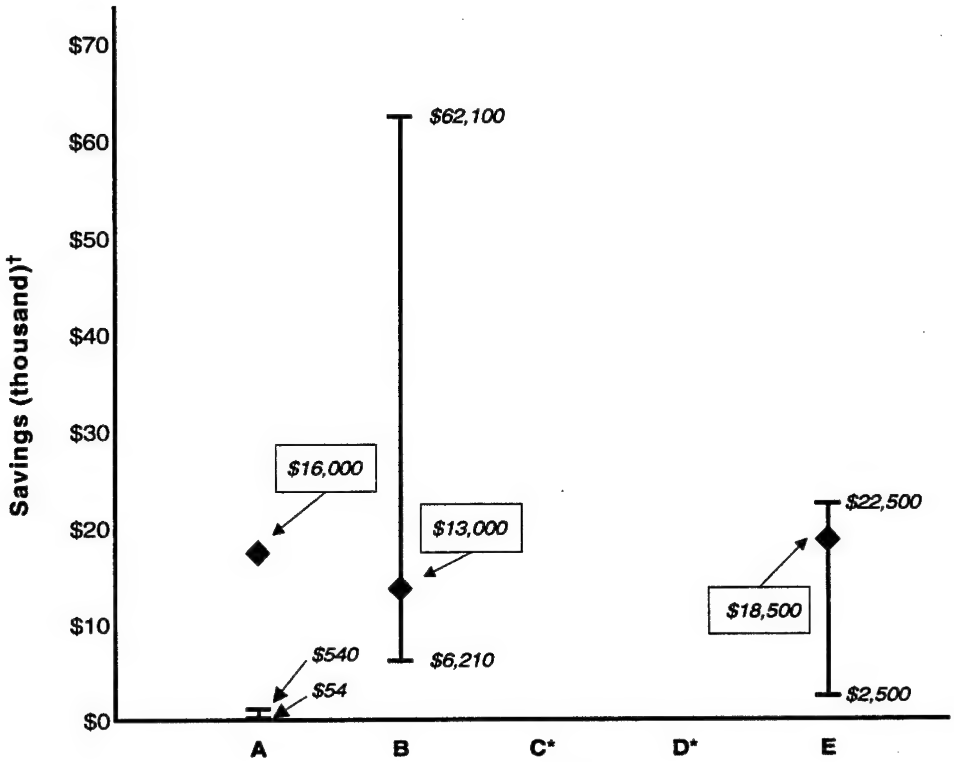
Table 4.1 Coarse Risk Analysis Recommendations

Recommendation	Change in RINH (Risk*)
Recommendation A — Consider modifying the ammunition dredger hoist to avoid crushing rounds and to incorporate personnel safety features, especially in regard to protecting hands/limbs. At least one significant personnel injury has occurred in the fleet while operating the hoist. This hazard is more pronounced in the lower ammunition magazine serviced by the hoist. At that location, personnel run the risk of (1) catching one or both hands in the hoist's folding cover doors when loading an ammunition round, resulting in possible minor injury, or (2) having one or both hands severely injured if caught in the folding doors and the hoist subsequently moves upward, which would occur if the operator's foot were to slip off a control pedal preventing hoist movement. The team also noted that hoist movement is stopped by contacting interlock switches (these interlocks may not be under any maintenance program). If these interlocks fail, an ammunition round may be crushed. Therefore, consider incorporating maintenance reviews of the ammunition dredger hoist into the Maintenance and Logistics Command (MLC) health and safety assessment process.	0.3 ($3,000)
Recommendation B — Consider modifying the guides that keep the floating dock in place to (1) help prevent damage to the piles and (2) reduce the potential for personnel injury during maintenance (being caught between the guide and piles). The guides were designed for a cylindrical wood pile. The current piles are octagonal (or some other multisided geometric shape) and are made of concrete. The shape and design of the guides damage the piles and require frequent maintenance. A new guide design suited for the piles design should be chosen.	0.072 ($720)

H Risk Index Number

* Estimated dollar/year savings if the recommendation is implemented.

Figure 4.6 displays the cost of implementing recommendations (shown in the boxes) as compared to the range of benefit (cost savings shown by the range) gained from the risk reduction. This range reflects the uncertainty of the frequency estimates in the analysis. This information aids decision makers when determining whether or not to implement a recommendation and in what order to implement recommendations.



* A reasonable estimate of savings is only possible after further review.

† Savings estimate assumes a $300,000 average cost of Class A/B mishaps, a $30,000 average cost of Class C mishaps, and a $3,000 average cost of Class D mishaps.

◆ Estimated total cost of implementing recommendation.

Note: Savings shown account for 50-year life of a vessel.

Figure 4.6 Cost/Benefit Analysis for Implementing Risk Reduction Recommendations

4.1.2 Detailed Risk Analysis

Detailed risk analysis techniques are standard, industry-proven hazard/risk analysis methods providing better resolution of potential loss scenarios and more certainty in risk characterization of loss scenarios. For this reason, the IRA process includes an assortment of detailed risk analysis tools that can be used for specific Coast Guard applications. Table 4.2 presents these techniques and the rationale for their selection. These methods typically require more advanced levels of training for successful application and are used only when more detailed analysis is warranted. Considering the high cost of maintaining qualified evaluators and the expected relative low frequency of their use, the Coast Guard will typically contract out for a detailed risk analysis.

Table 4.2 Detailed Risk Analysis Techniques

Technique	Rationale for Selection
What-if/Checklist	The simplicity and universal applicability of what-if/checklist analysis made it a natural choice for detailed hazard/risk analysis within the Coast Guard
WISE Analysis (Worker and Instruction Safety Evaluation Analysis)	The extensive nature of human involvement (especially procedural tasks) in virtually every Coast Guard mission/operation makes tools for thoroughly evaluating human error very important. The WISE analysis methodology combines into one technique an awareness of how people can impact processes and how processes can affect people
HAZOP Analysis (Hazard and Operability Analysis)	This technique is similar in nature to WISE, but is more applicable to fluid and thermal systems, which are abundant on Coast Guard vessels. It provides a more structured approach than a what-if/checklist analysis to identifying hazard and operability problems stemming from system deviations
FMEA (Failure Modes and Effects Analysis)	The Coast Guard uses mechanical and electrical systems/equipment extensively, making FMEA a natural choice for these applications when a less structured what-if/checklist analysis may be inadequate. (Although HAZOP analysis could be useful for analyzing Coast Guard fluid and thermal systems, FMEA can be equally effective in such applications for Coast Guard systems)
FTA/ETA (Fault Tree Analysis and Event Tree Analysis)	Because the Coast Guard has several systems with built-in redundancy and multiple levels of safeguards, modeling techniques for identifying complex combinations of equipment failures and human errors will be important for some situations. FTA/ETA are the most widely recognized and universally applicable techniques for these situations
HRA (Human Reliability Analysis)	The importance of human errors in Coast Guard operations and the complexity of some operations/procedures make HRA potentially useful for special situations as a supplement to other techniques (especially WISE analysis)
CCFA (Common Cause Failure Analysis)	When a situation is complex enough to require FTA/ETA, the potential for common cause failures cannot be overlooked. CCFA should always be applied (in some level of detail) with FTA/ETA

Section 7 of Attachment A discusses the detailed risk analysis techniques in more detail. Attachments D and E are examples of a detailed risk analysis performed for the Coast Guard.

4.2 Risk-based Safety Survey Process

Although risk analyses are useful for determining what types and levels of protection should be in place to effectively control the risks of potential losses, the benefits of such analyses can be realized only if proper field implementation of the planned protections is accomplished. Traditional safety surveys are typically audits using a systematic process (e.g., checklist) to assess compliance with requirements. They help to manage risk by ensuring that requirements specifying protections/safeguards are being implemented correctly.

The risk-based safety survey process uses predictive as well as historical risk information to focus survey resources on issues associated with the most significant risks. A risk-based safety

survey helps the organization manage risk by ensuring that both internal/external requirements specifying protections/safeguards and other safeguards identified in the coarse risk analysis are being implemented correctly (See Figure 4.7). The process also includes methods for determining the root cause of deficiencies and focusing corrective action resources on the most significant risk issues.

Coarse Risk Analysis
Safeguard
Boom is inspected annually

Risk-based Safety Survey	
Evaluation Point	**Requirement**
Are booms tested annually?	COMDTINST M90006.B
Is the date of the last boom test stenciled near the label plate in a location where it is clearly legible?	COMDTINST M90006.B

Figure 4.7 Basis for the Risk-based Safety Survey Process

The objectives of the risk-based safety survey process include:

- Focusing survey attention on the most significant risks
- Providing more objective prioritization of findings than traditional surveys
- Allowing more efficient use of survey resources
- Resolving root causes of findings
- Developing safeguard dependability information
- Improving Coast Guard standards and requirements

A risk-based safety survey involves:

- Focusing field observations and reviews on the most risk significant areas
- Identifying nonconformances to requirements as well as nonconformance trends through interviews with personnel, field observations, and documentation reviews
- Determining the underlying root cause(s) of findings

- Prioritizing the findings and resolving higher risk findings first to efficiently and economically use resources
- Tracking the resolution of findings to ensure recommendations for correcting problems are resolved in a timely manner

The risk-based safety survey process places the responsibility and authority for ensuring that planned protections are in place and working effectively on the unit commanding officers and their staffs. The units must understand the required protective measures and make implementation a high priority for effective loss prevention. The risk-based safety survey process assumes that acceptance of this basic obligation exists and that units are conducting their own self-surveys to verify their conformance with established requirements to supplement risk-based safety surveys by third parties (e.g., MLC personnel independent of the unit being evaluated). These third-party surveys complement (not replace) unit self-surveys.

4.2.1 Risk-based Safety Survey Steps

There are five major steps in the risk-based safety survey process:

(1) Plan a safety survey — Planning a survey involves identifying the scope of the survey and preparing for the survey. A key factor in the planning process is the risk prioritization of the evaluation points (checklist items). The risk associated with each evaluation point is determined by combining information from:

- an applicable coarse risk analysis using the link shown in Figure 4.7,
- past mishaps (losses), and
- past safety survey findings.

(2) Assess the requirements/evaluation points and record findings — This task is the actual survey of the unit. Survey team members canvass the unit, reviewing evaluation points. The survey includes equipment inspections, personnel interviews, and documentation reviews. Findings are deficiencies in meeting the intent of an evaluation point.

(3) Identify root causes of findings — Determining the underlying causes of a deficiency and correcting them helps to ensure that the deficiency does not occur again and prevents the underlying causes from contributing to other types of deficiencies and losses.

Root cause analysis should be performed at some level of detail for each finding. For some findings, the simple question "why?" is enough to determine a root cause. Other findings may require more rigor (e.g., 5 Whys technique, Root Cause Map™ technique) to find the root causes. The level of detail and the number of findings investigated with root cause analysis is left to the discretion of the survey team.

(4) Determine the risk impact of findings — This step of the process involves assigning a relative risk weighting to each finding that characterizes the finding's potential impact on unit risk (from the coarse risk analysis). This step uses the relationship shown in Figure 4.7. Risk impact is the foundation for prioritizing the findings for resolution and other tasks in the safety survey process.

(5) Document the results and resolve the findings — The safety survey visit is concluded with an outbrief highlighting the results of the survey. The results are also documented in a safety survey report that is submitted to the unit command, and the findings are documented in a findings database. These steps are discussed in significant detail in Section 8 of Attachment A.

4.2.2 Risk-based Safety Survey Results

The risk-based safety survey process provides feedback about the effectiveness of safeguards designed to control risk of potential losses. This feedback is in the form of findings. Figure 4.8 is an example of determining the risk impact of a finding. All findings from a risk-based safety survey would be analyzed and prioritized so they can be resolved in a cost-effective manner and so that higher risk issues are addressed first. Section 8 of Attachment A provides the details of obtaining this risk-based safety survey result and others. Attachment F provides an example of a risk-based safety survey that was performed on a Coast Guard vessel.

Figure 4.8 shows the determination of the risk impact of a risk-based safety survey finding. The method for this determination involves estimating the change in risk of the coarse risk analysis deviation(s) associated with the evaluation point if the finding (deficiency in a safeguard) is left uncorrected. The revised frequency scores in Figure 4.8 represent the characterization of the coarse risk analysis deviation if the finding is left uncorrected. The change in RIN (with risk expressed within parentheses as increased dollar/year loss) is associated with a risk impact level.

Finding	Evaluation Point	Affected Deviation (Operation/ Evolution *Function* Deviation)	Baseline Frequency Scores A/B	C	D	Revised Frequency Scores A/B	C	D	Change in RIN† (Risk*)	Risk Impact
No record of a crane inspection being performed for 2 years	N003	**Working aids to navigation** *Operating lifting equipment* Loss of support	2	3	4	5	6	7	9.0 ($90,000)	Medium

† Risk Index Number
* Estimated economic risk impact based on a change in risk of an associated coarse risk analysis deviation.

Figure 4.8 Risk Impact of a Risk-based Safety Survey Finding

Figure 4.9 is an example of the results of a root cause analysis of a finding. There were two root causes discovered for this finding, and two actions were suggested.

Finding	Root Cause(s)	Suggested Actions
Portable winch cable had not been weight tested in 3 years **Background** Three years ago, the Coast Guard vessel purchased two portable winches for engine room maintenance. The vessel had previously not had this type of equipment in its inventory	No policy or procedure to ensure new acquisitions are added to the vessel test and inspection program No policy or procedure requiring personnel to verify that certifications were up-to-date before using equipment	Develop guidance for adding new acquisitions to appropriate equipment logs such as test and inspection programs Develop guidance verifying certifications of equipment before use, and train personnel on the guidance

Figure 4.9 Results of a Root Cause Analysis

4.3 Risk Analysis and Risk-based Safety Survey Process Integration

The risk analysis and risk-based safety survey processes are tightly integrated through an exchange of important risk information. Figure 4.10 shows the information exchanges. The integration of the two processes improves the Coast Guard's ability to manage the risks associated with its operations.

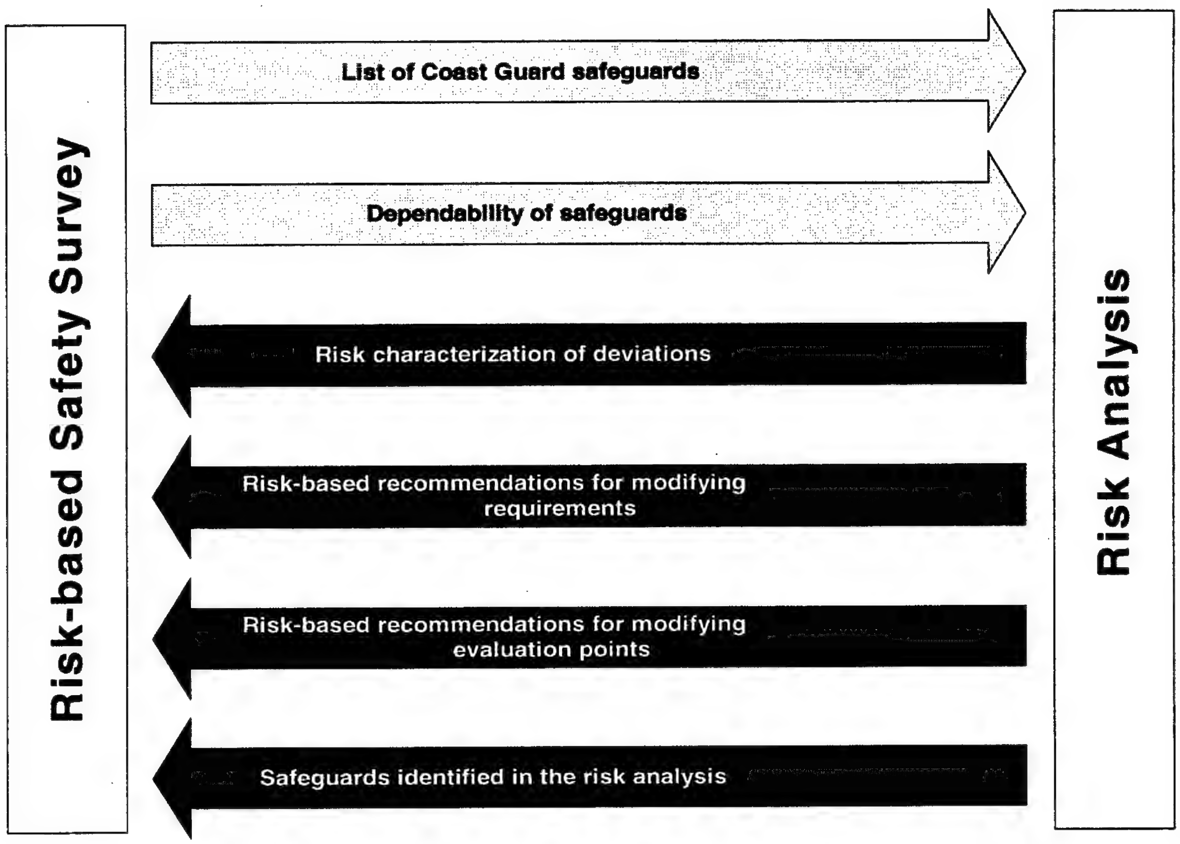


Figure 4.10 IRA Information Exchanges

4.4 Making Decisions Using the IRA Process

The IRA process is a management tool that can be used at each stage of the life cycle of activities to make decisions. The specific part of the IRA process used will depend on the type of risk-based information required for the decision a Coast Guard manager is trying to make. As an example, Table 4.3 provides vessel life cycle activities, how the risk-based information from the IRA process may be used to make decisions, and example outcomes of using the information.

Sections 5 and 8 of Attachment A expand this table to include specific element(s) of the IRA process that help make these decisions.

Table 4.3 Uses of the IRA Process for Vessel Life Cycle Activities

Use of IRA Process	Example Outcomes
Procurement	
Identification of major hazards and associated risks (including human factors issues) and required controls while developing bid specifications for major acquisitions (e.g., new vessels or major onboard systems)	Requiring built-in redundancy for specific components of a vessel's automated navigation system
Risk-based selection among competing design alternatives for major acquisitions	Determining (and documenting) that Design A provides "best value" to the Coast Guard because it poses significantly less risk of major losses than Design B, which is slightly less expensive
Construction, Fabrication, and Commissioning	
Identification of design weaknesses, safe operating limits, critical preventive maintenance tasks, human factors issues, etc., for selected systems (i.e., those that could lead to losses of interest) after the final design is complete for major acquisitions	Requiring an audible alarm and semiannual calibration of fathometers for a vessel
Evaluation of proposed changes and identified nonconformances from the approved design	Approving a proposed field change (or a recognized nonconformance) in the routing of a high-pressure steam line because the new routing poses no identifiable increase in risks to personnel or equipment
Vessel Operations and Maintenance	
Identification of precautions to be taken in performing operations outside of prescribed limits (case-by-case basis for decisions made by vessel-board personnel)	Establishing more stringent maneuvering restrictions and additional watch requirements for performing search and rescue (SAR) operations in extreme weather conditions that would normally cause discontinuation of the operation
Identification of precautions to be taken in preparation for performing operations when relevant vessel systems will be unavailable (case-by-case basis for operations/efficiencies identified by vessel-board personnel)	Posting additional watches and conducting special operations briefings before conducting an operation
Evaluation of proposed changes and identified nonconformances from the standard vessel configuration (case-by-case basis for changes suggested and approved by vessel-board personnel)	Rejecting a request to temporarily store equipment on the deck while a storage locker is being replaced because the movement of the equipment under expected high seas could lead to losses of interest
Identification of weaknesses in procedures that could lead to losses of interest (case-by-case basis for procedures developed and approved by vessel-board personnel)	Revising vague steps of a procedure (e.g., "open the valve slightly") because a human error associated with the operation could lead to a loss of interest
Area, District, or Group Management of Operations and Maintenance	
Identification of design weaknesses, safe operating limits, critical preventive maintenance tasks, human factors issues, etc., for selected systems (i.e., those that could lead to losses of interest) aboard existing ships that did not receive such reviews before being placed in operation	Recommending redesign of a small craft launching system component that could inadvertently trigger a release of a boat

Table 4.3 Uses of the IRA Process for Vessel Life Cycle Activities (cont'd)

Use of IRA Process	Example Outcomes
Area, District, or Group Management of Operations and Maintenance (cont'd)	
Identification of safe operating limits (from an operations/command perspective rather than a hardware system design perspective, which was addressed during design reviews) and preferred precautions to be taken if operating outside of such restrictions	Prohibiting aircraft fueling operations and other flammable material handling activities until disabled onboard firefighting systems are returned to service, but allowing emergency fueling operations if another onboard pump can be rigged to temporarily provide adequate firefighting capability
Identification of critical training topics, standard procedures necessary, etc., for preventing losses of interest	Deciding to write a special procedure and conduct special training for the proper way to launch a new type of small craft (because the operation is significantly different from similar operations with older small craft)
Identification of weaknesses in procedures and human factors issues that could lead to losses of interest (for standard procedures applicable to a class of vessels or the entire fleet)	Making the units of pressure referenced in a procedure (e.g., SI units) consistent with those commonly used aboard a vessel and on the vessel's gauges (e.g., English units) to help prevent confusion that could lead to an operating error
Evaluation of proposed changes for standard vessel configurations (case-by-case basis for changes approved by group/fleet officers)	Deciding (1) against a crew reduction aboard a WMEC-270 cutter because of unacceptable risks associated with degraded watch standards or (2) in favor of a crew reduction, provided that each vessel is equipped with new navigation and vessel detection systems
Monitoring profiles of risks for classes of vessels across the Coast Guard to help understand/manage risks at a fleet level	Determining that a specific class of vessel is the next to receive a major overhaul (or replacement) program because of high loss rates
Assigning measures of importance to safety inspection items to help prioritize responses to noted deficiencies	Deferring resolution of a few deficiencies noted during a safety inspection until next fiscal year because the deficiencies do not pose any significant risks of losses
Risk-based selection (including consideration of other factors, such as cost) among competing alternatives such as vessel deployment, mission assignments, etc.	Deciding to send Vessel A on an extended international tour because the potential for losses associated with (1) its tour and (2) its absence from its normal station are less than those for Vessel B
Decommissioning	
Risk-based selection (including consideration of other factors, such as cost and political pressure) among competing alternatives for vessel/station decommissioning	Deciding (and gaining support for the decision) to decommission Vessel B instead of Vessel A, even though there is some political support for keeping Vessel B in service
Identification of weaknesses in equipment used for decommissioning and associated procedures that could lead to losses of interest	Modifying the equipment and procedures used to de-inventory hazardous materials from a vessel while the vessel is being decommissioned

5. IRA Process Development

The Coast Guard recognized the potential benefit in using risk-based information to support decisions concerning the management and control of its assets. The RDC committed to developing a risk assessment process for providing this risk-based information. In 1995, the RDC teamed with JBFA to develop and test a Coast Guard risk assessment process, which became the IRA process.

The RDC and JBFA used a three-phased approach to develop the IRA process. Below is a brief description of each phase.

Phase 1 — identification of the Coast Guard's risk-based information needs, development of the coarse risk analysis technique, identification of relevant detailed risk analysis tools, development of the framework for the risk-based safety survey process, test applications of the coarse and detailed risk analyses, and development and training of Coast Guard safety professionals on the coarse risk analysis technique.

Phase 2 — refinement of the coarse risk analysis process, development of the risk-based safety survey process, integration of the two processes into the IRA process, validation of the IRA process on Coast Guard vessels, revisions to the training course developed in Phase 1, and training of additional Coast Guard personnel.

Phase 3 — modification of the IRA process for use on shore facilities and validation of the IRA process on Coast Guard shore facilities.

The following sections discuss each of the project phases, including the approach, results, and lessons learned (issues) associated with each phase.

Reminder: During the course of this research project, the term "hazard analysis" was changed to "risk analysis" to better describe the process. Therefore, the term "hazard analysis" will be found in many previous letters, reports, and other work products related to this project. These previous references to hazard analysis should now be interpreted as references to risk analysis.

5.1 Phase 1

The RDC and JBFA met with Coast Guard decision makers and safety professionals to gain understanding of the current Coast Guard processes used for assessing risk and the Coast Guard's expectations for a risk assessment methodology. From these discussions, the RDC and JBFA proposed that the risk assessment methodology consist of two elements: (1) a risk analysis process and (2) a risk-based safety survey process. In general, the risk analysis process would identify risks and provide risk reduction measures where appropriate, and the risk-based safety survey process would enhance the current safety survey process with risk-based information to help ensure that the safeguards designed to reduce risk are effectively implemented in the field. The objectives of Phase 1 were to (1) develop and test a risk analysis methodology and (2) develop the framework for a risk-based safety survey process.

5.1.1 Risk Analysis

From discussions with Coast Guard decision makers and safety professionals, the Coast Guard required a risk analysis methodology that would meet its risk-based information needs without overworking or underworking the issues. To accomplish this, the RDC and JBFA considered a methodology that could analyze issues at two levels of detail. The methodology would include (1) a coarse risk analysis (streamlined analysis) for assessing most situations and (2) a set of detailed risk analysis techniques for specific situations requiring better resolution of results and/or higher certainty in risk characterization of scenarios.

5.1.1.1 Coarse Risk Analysis

Approach

Once the Coast Guard's coarse risk analysis needs/expectations were identified, the RDC and JBFA began investigating what hazard evaluation technique (or combination of techniques) would best serve the Coast Guard as the basis for its coarse risk analysis approach. A collection of widely accepted hazard evaluation approaches were considered (e.g., checklist analysis, the traditional safety review, what-if analysis, the traditional process risk analysis, relative ranking tools, FMEA, and HAZOP analysis). Multiple approaches/formats were tested to determine how well they might meet the Coast Guard's needs. Through this refinement process, the RDC and JBFA developed a proposed coarse risk analysis process for the Coast Guard, recognizing that, based on test applications, additional revisions and improvements of the process would likely be

necessary. The proposed process was primarily based on the HAZOP analysis technique used in the petrochemical industry.

HAZOP is an inductive approach that uses a very systematic process for postulating deviations from the design intent for sections of systems and ensuring that appropriate safeguards are in place to help prevent losses. The approach generates qualitative descriptions of potential losses (deviations, causes, mishaps, and safeguards) as well as lists of recommendations for reducing risks. HAZOP was easily adapted to incorporate frequency estimates for potential losses and the operations/evolutions and functions of Coast Guard units.

The RDC and JBFA tested the proposed coarse risk analysis to evaluate the effectiveness and efficiency of the methodology by working with three different teams of Coast Guard personnel. These teams participated in mock risk analysis sessions, testing various parts of the proposed coarse risk analysis process. The lessons learned from the test application were used to modify the proposed process, and the baseline coarse risk analysis process was created.

As a test of the baseline methodology, the RDC and JBFA performed a coarse risk analysis on two vessel platforms, the *USCGC KENNEBEC* (a WLIC-160 vessel) and the *USCGC HARRIET LANE* (a WMEC-270 vessel).

In addition to testing the methodology, the Coast Guard wanted to ensure that Coast Guard safety professionals could be trained to perform the coarse risk analysis process. To accomplish this, the RDC and JBFA developed a week-long training course that included discussions on risk and general risk analysis as well as training on performing the coarse risk analysis process. This training course was conducted for both MLC-Pacific (MLC-PAC) and MLC-Atlantic (MLC-LANT) safety professionals and included simulated analyses aboard actual Coast Guard vessels.

Results

In general, the test applications of the methodology on *USCGCs KENNEBEC* and *HARRIET LANE* proceeded very well. For a high-level analysis, the coarse risk analysis methodology effectively highlighted the most significant risk contributors and provided enough detail to develop meaningful recommendations for reducing risk. The results of the analyses provided the Coast Guard with the appropriate level of detail for making risk-based decisions.

The training session was successful in teaching Coast Guard safety professionals to perform the coarse risk analysis process. During the session, the safety professionals provided valuable feedback concerning the methodology that the RDC and JBFA could use to improve the effectiveness and efficiency of the process. A workshop was conducted at the end of the week, providing the safety professionals with the opportunity to use the analysis technique on several vessel activities. The workshop successfully demonstrated that the coarse risk analysis process was sufficiently structured to be used by Coast Guard personnel who have modest risk analysis experience.

The RDC and JBFA planned to refine the coarse risk analysis process in Phase 2 and modify the process where appropriate for integration with the proposed risk-based safety survey process.

Lessons Learned

Two significant issues arose during Phase 1:

(1) While testing the baseline coarse risk analysis (and also during the training session), the RDC and JBFA found that it worked best to focus the analysis on one operation/evolution at a time. The baseline methodology was restructured to provide this focus. This is in contrast to evaluating abnormal conditions (deviations) across all operations/evolutions simultaneously. The modification improved the subject matter experts' understanding and participation in the analysis.

(2) As the baseline coarse risk analysis was tested, it was apparent that a software tool was needed to help perform the analysis, maintain the analysis data, and manipulate the analysis data into various results.

5.1.1.2 Detailed Risk Analysis

Approach

Many types of detailed risk analysis techniques (both qualitative and quantitative in nature) have been developed over the past 30 to 40 years to help analysts in a variety of industries systematically assess the hazards in their activities and the levels of risk associated with those hazards. The RDC and JBFA investigated what hazard evaluation techniques would best serve the Coast Guard as detailed risk analysis tools in specific situations. Rather than spending

resources trying to create new techniques (or significantly customizing existing techniques) for the Coast Guard, the RDC and JBFA approached this phase of the risk analysis project by recommending that the Coast Guard adopt a small set of the widely recognized, standard hazard evaluation techniques that provide a broad range of analysis capabilities as part of the Coast Guard's overall risk analysis system. The rationale for using "off-the-shelf" techniques included the following points:

- Existing detailed risk analysis techniques have been repeatedly used in a variety of applications with strong histories of success when techniques are prudently selected for analysis applications
- The coarse risk analysis methodology will satisfy most of the Coast Guard's hazard evaluation needs; therefore, detailed risk analysis methodologies are somewhat less important and do not warrant the resources required to create specialized tools
- The expected use of outside contractors (in larger analyses) to support Coast Guard hazard evaluation needs is simplified when standard analysis approaches are specified
- Users/reviewers of risk analysis results have greater confidence in the quality of results when widely recognized methodologies are followed

To demonstrate the effectiveness of a detailed risk analysis technique, the RDC and JBFA reviewed WMEC-270 small boat operations and WLIC-160 aids to navigation (ATON) deck operations using several techniques. Because these activities were included in the testing of the baseline coarse risk analysis, choosing them provides an opportunity to compare detailed risk analysis results and coarse risk analysis results.

Results

The standard list of detailed risk analysis techniques was identified. This list is documented in Section 4.1.2 of this report, Table 4.2. Section 7 of Attachment A contains a detailed discussion of these techniques.

The assessment of WMEC-270 small boat operations was performed using the WISE analysis technique coupled with a human error (error-likely situation) review and a procedural review. The analysis confirmed the risk assessment performed by the coarse risk analysis. However, the detailed study provided a more focused review of small boat operations and thus developed recommendations that the coarse risk analysis would not have produced (nor should have produced due to the level of resolution needed from the coarse risk analysis). The analysis

was very successful in demonstrating the benefits of detailed risk analysis. Attachment D contains the results of this detailed risk analysis.

The detailed analysis of WLIC-160 ATON deck operations was performed using the what-if analysis technique. This technique was considered most appropriate to ATON operations because (1) personnel experienced in ATON operations were available for valuable brainstorming discussions and (2) more structured analysis techniques (such as HAZOP or FMEA) were not needed to assess the risks associated with the complexity of this operation. As expected, the what-if analysis refined the coarse risk analysis results with more detailed descriptions of specific causes of certain mishaps and additional recommendations for risk reduction. This analysis was also a successful demonstration of a detailed analysis technique. Attachment E contains the results of this detailed risk analysis.

Lessons Learned

The detailed risk analysis process worked well, and no significant issues arose as a result of Phase 1.

5.1.2 Risk-based Safety Survey

Approach

The Coast Guard relies heavily on conformance to safety standards to ensure the safety of its personnel and assets. Safety professionals within the Coast Guard are very familiar with the safety standards and their application. The Coast Guard wishes to capitalize on this corporate knowledge to improve safety standards and unit risk assessments.

The RDC and JBFA met with Coast Guard safety professionals to determine the current state of assessing and implementing safety standards. The RDC and JBFA sought to understand how the safety standards could be organized and prioritized from a risk impact perspective to improve the Coast Guard safety survey process. The Coast Guard desired to maximize the benefit of safety surveys while reducing the amount of time required by the Coast Guard safety professionals to perform safety surveys.

The RDC and JBFA polled private industry and the Navy to understand their approach to performing safety surveys and using safety survey information. As a result of this investigation,

the RDC and JBFA identified two significant ways to meet the Coast Guard's desires: (1) focus safety surveys on higher risk issues and (2) prioritize safety survey findings for efficient resolution.

The RDC and JBFA investigated ways to focus safety surveys on the higher risk issues by prioritizing the survey evaluation points according to the risk. The most logical method for this prioritization appeared to be by using risk-based information from the risk analysis process. Focusing on the higher risk issues ensures an effective survey of the dominant risk contributors while potentially reducing the work load of the safety professionals. Also, reviewing the risk associated with evaluation points can eliminate requirements that add little value to the safety survey process.

The RDC and JBFA also investigated methods to effectively and efficiently focus Coast Guard resources on resolving findings (or deficiencies) identified as a result of the safety survey. A method is needed for prioritizing findings so that resources can be focused on high risk issues. To prioritize findings, the risk-based information from the risk analysis process can be used for determining the impact a finding has on the risk of a Coast Guard unit. Once the risk impact of a finding is determined, the Coast Guard can identify a resolution order.

Results

The RDC and JBFA proposed a framework for a risk-based safety survey process. The process developed from this framework would meet the Coast Guard's risk-based information needs and desires for an efficient and effective safety survey process. The risk-based safety survey process would be developed and validated in Phase 2. Where appropriate, the development would focus on integration with the risk analysis process.

Lessons Learned

The risk-based safety survey framework was developed, and no significant issues arose as a result of Phase 1.

5.2 Phase 2

The objectives of Phase 2 were to refine the risk analysis process, formalize the risk-based safety survey process, integrate the processes into the IRA process, train Coast Guard personnel

to conduct a risk analysis and a risk-based safety survey, and validate the IRA process on vessel applications. The work on the risk analysis process consisted of refinement of the coarse risk analysis process and validation of the coarse and detailed risk analysis processes on vessel applications. The proposed risk-based safety survey process from Phase 1 was formalized and validated on a vessel application. Integration of the two processes was tested during validation of the risk-based safety survey process. The training course developed in Phase 1 was updated to reflect modifications to the processes, and additional Coast Guard personnel were trained.

5.2.1 Coarse Risk Analysis

Approach

The coarse risk analysis process was refined to address the issues identified in Phase 1. The major change in the process was to restructure the analysis around operations/evolutions and focus on one operation/evolution at a time during the analysis. The RDC and JBFA validated the refined coarse risk analysis by performing an analysis of the operations/evolutions of the *USCGC MELLON* (a WHEC-378 vessel) during a 1-week analysis session. Coast Guard safety professionals led the validation exercise with the assistance of the RDC and JBFA. This test application also validated the success of the training course (described in Phase 1) in equipping Coast Guard safety professionals to lead these analyses.

In support of the test analysis, an off-the-shelf software tool was adapted for documenting the raw data from the analysis.

Results

The coarse risk analysis validation on the *USCGC MELLON* proved to be successful and very beneficial in revealing potential areas for improvement in the coarse risk analysis process. The analysis team successfully analyzed the majority of the operations/evolutions of the *USCGC MELLON*, developed a risk profile for the vessel, and generated numerous risk reduction recommendations.

Lessons learned from using the software tool to document the analysis were incorporated into the development of a software tool to support the IRA process.

The Coast Guard safety professionals successfully led the test application. The training they received during the week-long training course (described in Phase 1) proved to be successful in preparing them for leading a coarse risk analysis.

Lessons Learned

Two significant issues arose during the validation of the coarse risk analysis:

(1) The RDC and JBFA wrestled with the most appropriate and effective method to represent the RIN, which is a representation of risk associated with Coast Guard activities. The baseline coarse risk analysis method for calculating the RIN used a simple method that included risk scores for Class A/B and Class C/D mishap categories. Testing the methodology revealed that this method inflated the risk contribution of high consequence losses (Class A and Class B mishaps) in the RIN. To correct this, the method for calculating the RIN was modified. The new method was tested and corrected the initial problem, but introduced another. Using the new method for calculating the RIN, the lowest consequence losses (Class D mishaps) became the dominant factor in the Class C/D mishap category score. The new method resulted in Class D mishaps inflating the risk contribution of the Class C/D mishap category in the RIN.
The final resolution was to divide the Class C/D mishap category into a Class C mishap category and a Class D mishap category. The revised methodology assigns risk scores to Class A/B, Class C, and Class D mishaps. This change was incorporated into the methodology and tested in Phase 3.

(2) Functions as defined in the baseline coarse risk analysis process describe (1) key activities for accomplishing operations/evolutions (e.g., *maneuvering the vessel*) or (2) key activities for controlling different types of hazards (e.g., *controlling physical hazards*). This approach provided sufficient analysis structure to identify important problem areas, but did have some weaknesses. The approach segregated safety-related issues from operational issues, overlooked the interrelationship of several functions, and overlooked potential problems associated with loss of capability to perform key activities as well as poor quality in performing those activities.

These weaknesses caused some confusion for analysis team leaders and team members. In addition, some Coast Guard safety professionals expressed concern about the message that

separating "safety" and "operational" issues sends to Coast Guard managers (i.e., Would it lessen the impact of safety concerns?).

The resolution for this issue involved revising function definitions (and associated deviations) to focus on fundamental activities that occur for a unit (e.g., *operating vessels, vehicles, aircraft, or equipment*; *operating/maintaining structures*; and *providing services/utilities*). A diverse set of deviations is included for each function. These deviations cover (1) loss of the function, (2) incorrect execution of the function, and (3) a variety of hazardous exposures that could occur while performing the function (including associated maintenance activities). The new functions were tested in Phase 3.

5.2.2 Detailed Risk Analysis

Approach

In Phase 2, the Coast Guard desired to perform an additional test of a detailed risk analysis technique. The detailed risk analysis approach meets the Coast Guard's detailed analysis objectives and was not modified from Phase 1.

The Coast Guard chose to perform an analysis of incinerator installations on board WHEC-378 vessels. The incinerator installation on board the *USCGC MUNRO* was selected by the Coast Guard as the subject of the detailed risk analysis, with the intent of applying any lessons learned from the analysis to that installation (as appropriate) and to subsequent installations on other cutters (especially other cutters in the same class).

Results

The RDC and JBFA successfully performed a what-if/checklist analysis on the incinerator installation. Coast Guard vessel and shore-based personnel participated in the analysis. Several recommendations for improving the incinerator installation were generated from the detailed risk analysis.

Lessons Learned

The detailed risk analysis process worked well, and no significant issues arose as a result of Phase 2.

5.2.3 Risk-based Safety Survey (Phase 2)

Approach

The risk-based safety survey process proposed in Phase 1 was formalized and integrated with the coarse risk analysis process. The RDC and JBFA determined the information required from the coarse risk analysis process and developed detailed steps for prioritizing evaluation points and risk ranking survey findings for resolution. Root cause analysis techniques were investigated for appropriately resolving findings. The RDC, JBFA, and MLC-PAC (kse) validated the risk-based safety survey process on the *USCGC SHERMAN* (a WHEC-378 vessel). By performing the process on a WHEC-378, integration of the coarse risk analysis and risk-based safety survey could also be tested.

Results

The RDC and JBFA used the results of the WHEC-378 coarse risk analysis and past safety survey findings information (from MLC safety professionals) to prioritize the safety survey evaluation points. The safety survey tested on the host vessel (*USCGC SHERMAN)* focused on the higher risk evaluation points. The survey produced several meaningful findings. The RDC, JBFA, and MLC safety professionals used the IRA process to rank the findings according to their impact on overall vessel risk. The risk-ranked findings were prioritized for resolution and presented to the vessel command. The IRA process identified that some findings did not require immediate resolution due to their very low risk impact to the vessel.

The validation was successful in testing the risk-based safety survey process and the methodology for integrating the coarse risk analysis and risk-based safety survey processes. Attachment F documents the results of this risk-based safety survey and is included as an example of a risk-based safety survey. (The ultimate formats of reports for the Coast Guard are left to the individual commands.)

Lessons Learned

The risk-based safety survey process worked well, and no significant issues arose as a result of Phase 2.

5.3 Phase 3

The objective of Phase 3 was to refine the IRA process for shore facility applications and to validate the process. The RDC and JBFA reviewed the coarse risk analysis and risk-based safety survey processes to determine differences in applying these processes to shore facilities. Upon review, the risk-based safety survey process appeared to be the same when applied to either type of Coast Guard unit and would not need modifications. However, the coarse risk analysis would need modifications and would also need to be tested on shore facilities. The main objective of Phase 3 was to make necessary adjustments to the coarse risk analysis process and test it on shore facilities. A secondary objective was to test the risk-based safety survey process with unit safety supervisors to reduce the monitoring burden from the MLC staffs. In addition, the RDC and JBFA needed to ensure that these adjustments maintain the effectiveness of the process when it is reapplied to vessels.

5.3.1 Coarse Risk Analysis

Approach

When applying the coarse risk analysis process to shore facilities, the RDC and JBFA sought to maintain consistency (to the maximum extent possible) with the coarse risk analysis process as it is applied to vessels. The RDC and JBFA tested portions of the process on hypothetical shore facility situations and found that the core structure of the analysis technique also worked well for shore facilities. However, three major issues were discovered: (1) the operations/evolutions are different for shore facilities, (2) some functions are not applicable to shore facilities and others are required, and (3) the coarse risk analysis process needs to be able to assign risk to a specific location for shore facilities (when needed).

Shore facilities have a different mission from vessels and, therefore, their operations/ evolutions are different. In fact, different types of shore facilities (e.g., Integrated Support Commands [ISCs], Marine Safety Offices [MSOs]) have a different set of operations/evolutions due to their different missions. A new set of operations/evolutions was developed for each type of shore facility.

Several vessel functions (e.g., *providing ballasting services*) are not applicable to shore facilities, and several shore facility functions (e.g., *operating powered vehicles*) are not included in the vessel function list. Upon further research, the RDC and JBFA also found that different

types of shore facilities have a slightly different set of functions (the MSO function list contains a number of inspection functions). The RDC and JBFA developed the shore facility function lists (ISC and MSO) from the vessel function list by making the necessary modifications to the vessel list.

Because shore facilities involve numerous types of buildings and structures (e.g., piers, parking lots, roads), it was obvious that a method for assigning risk to individual locations would improve the effectiveness of the coarse risk analysis for shore facilities. The RDC and JBFA modified the methodology in such a way that the resulting modified coarse risk analysis process could be used for shore and vessel applications.

The modified approach evaluates deviations in the same manner as before, except the analysis team will assess how the deviation risk is distributed across the different locations within the facility (if more than one location is an issue). The new methodology is flexible enough to allow the analysis to proceed without assessing location risk. This gives the Coast Guard analyst the option to perform the analysis as before (without assigning risk to locations) if that information is needed.

The RDC and JBFA tested the resulting coarse risk analysis process on an ISC and an MSO shore facility. The RDC and JBFA, with the support of MLC-LANT (kse), also tested the modified process on a WMEC-210 in support of the Paragon project.

Results

The RDC and JBFA validated the new coarse risk analysis process on the ISC in Seattle, Washington, the MSO in New Orleans, Louisiana, and the *USCGC VENTUROUS* (a WMEC-210 vessel). The ISC analysis included assessing the risk associated with locations. The MSO and WMEC-210 analyses did not assess location risk. All three validations produced risk profiles of the facilities and vessel, and meaningful recommendations for reducing risk. The minor modifications to the coarse risk analysis process were successful. They made the overall IRA process a better risk assessment tool and maintained the ability to assess vessel applications. Attachment B contains the results of the WMEC-210 coarse risk analysis, and Attachment C contains the results of the ISC coarse risk analysis.

Lessons Learned

The coarse risk analysis process worked well, and no significant issues arose as a result of Phase 3.

6. Future Development

The next step for the IRA process is to develop a management system that will manage the IRA process, generate the required IRA process data, and ensure the data are accessible to Coast Guard managers for decision making. Work will focus on the areas described below.

Developing an IRA Process Software Tool

Because of the complexity involved with managing and manipulating the data produced by the IRA process, the Coast Guard identified the need for a software tool to assist in the implementation of the process. Development of the IRA process software tool began during Phase 3. The RDC and JBFA used the experiences gained from applying the IRA process on shore and vessel applications to develop a conceptual design of the software tool. The conceptual design was accepted and work began on various software modules. The next step is to test a beta version of the software. The IRA process beta version of the software was delivered in the Fall of 1998 and will be released by the R&D Center early in 1999.

Developing a Management System for the IRA Process

JBFA will work with the Coast Guard to develop a management system for the IRA process. This system will define the roles and responsibilities involved in implementing the IRA process, define the management of the IRA information, and define the interaction of the IRA process with other Coast Guard management systems.

Improving Related Coast Guard Management Systems

JBFA will work with the Coast Guard to identify improvements to Coast Guard management systems that the Coast Guard could make to reduce loss exposure. This will include:

- Identifying deficiencies in current practices where new management systems might be needed to address all aspects of loss prevention

- Improving existing management systems to enhance their effectiveness and/or efficiency in loss prevention

- Prototyping new management systems

- Exploring how the Coast Guard can measure and track the performance of management systems and their effects on loss prevention

7. Concluding Remarks

By understanding the needs of the Coast Guard and following the guiding principles, the RDC and JBFA developed useful techniques and tools that should be both efficient and effective in helping the Coast Guard control its losses and reduce its loss exposure over time. Validation proved the IRA process to be feasible and useful in assessing a wide variety of Coast Guard operations and facilities at various levels of detail. Coast Guard personnel are successfully using the IRA process to understand the change in risk when making changes in vessel staffing and operating procedures. Continued implementation of the process will provide Coast Guard management with information for risk-based decision making, as well as direction for the efficient and effective use of limited Coast Guard resources.

Attachment A

Integrated Risk Assessment (IRA) Manual

The *IRA Manual* is a detailed description of the IRA process. The manual includes an overview of how losses occur, a discussion of risk and common risk analysis methodologies, an overview of the IRA process, and step-by-step instructions for performing and managing the IRA process. This manual is part of the course for training Coast Guard personnel to perform the activities in the IRA process. The analysis of a WHEC-378, with Coast Guard personnel leading the analysis, demonstrated that the course is sufficient to train Coast Guard personnel to conduct assessments.

The information contained in this manual consists of facts, concepts, and principles for conducting hazard evaluations using qualitative and quantitative methods. JBF Associates, Inc. assumes no liability for this material beyond the material's intended purpose of providing general information about hazard evaluations and safety assessments.

DO NOT attempt to operate any facility, unit, process, system, or equipment based solely on the information provided in this manual. Refer to your own operating procedures, equipment descriptions, operating limits, safety and health considerations, etc.

IRA Manual

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Acknowledgments

This manual was produced by the United States Coast Guard (Coast Guard) Research and Development Center (RDC) during a multiyear project sponsored primarily by the kse branch at Coast Guard headquarters. This project has systematically examined the various aspects of risk management within the Coast Guard and sought to develop and/or improve Coast Guard methods/systems/tools to most effectively and efficiently prevent losses. The methods presented in this manual are the result of development, testing, and review efforts performed by individuals representing many groups associated with the project:

RDC. The RDC facilitated the project through strong leadership and an ever-present customer focus. Mr. William Jones, the project manager at the RDC, skillfully guided the project and used his own experience as a commissioned officer within the Coast Guard to focus work on the most significant risk management issues for the Coast Guard.

KSE. The kse branch at Coast Guard headquarters provided the vision of what the Coast Guard was trying to achieve through its risk management systems/tools and served as the principal communication link with other branches of the Coast Guard during development and testing work. Captain Walt Hanson, and later LCDR Rick George, served as the key project sponsors, along with input from many of the other professionals within the kse branch (and other closely related branches).

MLCs. As key players in Coast Guard risk management activities, the health and safety staffs within both MLC-PAC and MLC-LANT provided much insight into (1) the current status of Coast Guard risk management systems and (2) the practicality of proposed ideas for changes in those systems. In addition, the MLC health and safety staffs participated in numerous tests/reviews of the methods/tools, each time providing suggestions for making the methods/tools more effective and/or easier to apply. Although many contributed, input from Mr. Ken Koutz (MLC-PAC), Mr. Glenn Sheridan (MLC-LANT), and Mr. John Ferrioli (MLC-LANT) was consistently timely and valuable.

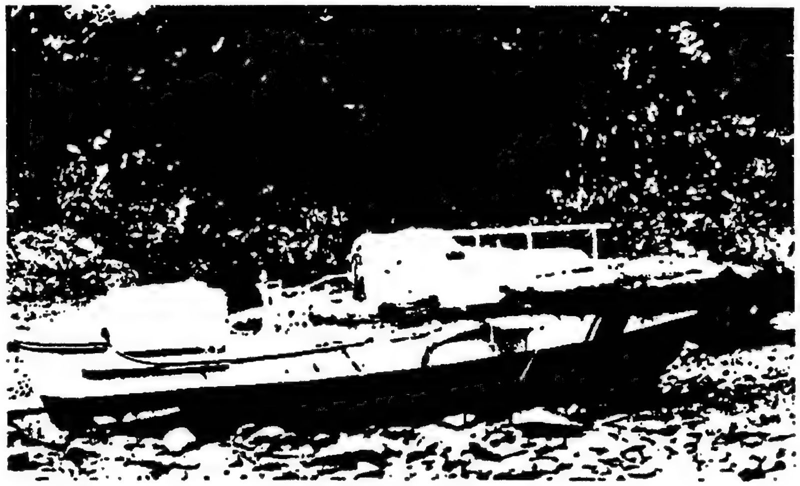
Units. Several units participated in developing/testing the methods in this manual, including *USCGC HARRIET LANE, USCGC KENEBEC, USCGC LEGARE, USCGC MELLON, USCGC SHERMAN* (SF), ISC Seattle, and MSO New Orleans. The willingness of the unit personnel to participate in tasks above and beyond their normal duty and to help improve the methods/tools by providing practical advice has been greatly appreciated.

Acknowledgments (continued)

JBF Associates, Inc (JBFA). Based on many years of experience with numerous industries and government organizations, JBFA provided the loss prevention and risk management expertise needed to develop the risk management methods/tools discussed in this manual. JBFA also provided this manual to the RDC as a project deliverable. Mr. David Montague and Mr. Vernon Guthrie have managed JBFA's work for the RDC. We appreciate the technical expertise of Ms. Emma Daggett, Ms. Jill Farmer, Mr. Andy Huff, Mr. Lee Vanden Heuvel, and Mr. David Walker in developing and reviewing these materials. The skill and craftsmanship of Ms. Leslie Adair, Ms. Maureen Hafford, Ms. Nicole Lepoutre-Baldocchi, Ms. Cheryl Ribes, Ms. Mary Tinnel, and Ms. Maleena Watson in editing and producing these materials are also greatly appreciated.

United States Coast Guard
IRA Manual

Section 1
How Mishaps Occur



Cost of Mishaps

Mishaps rob all of us

Our personnel. Mishaps can threaten the safety and long-term health of our personnel.

The public. Mishaps can also threaten the safety and long-term health of others.

Our organization. Mishaps directly affect organizational performance by

- disrupting production/missions,
- reducing efficiency and increasing expenses, and
- creating negative publicity.

The environment. Mishaps can cause immediate and/or long-term damage to the environment.

Our customers. Mishaps ultimately affect customers through

- our inability to deliver services/products and
- increased costs for services/products.

Some recent major Coast Guard losses

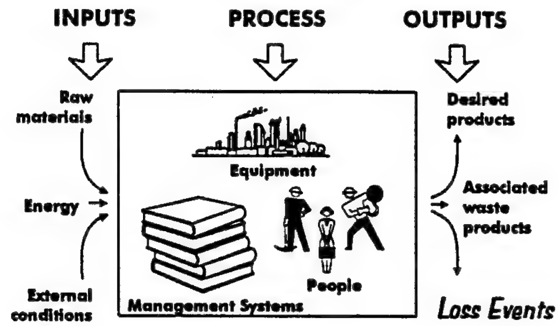
- *COWSLIP* (1997, >$7M)
- *MESQUITE* (1990, >$37M)
- *BLACKTHORN* (1980, 23 deaths)
- *CUYAHOGA* (1978, 11 deaths)

Economics of Coast Guard losses and loss prevention*

Year	Cost of Losses	Cost of Loss Prevention Efforts	Total Cost
1996	>$10.4M	>$1.5M	>$11.9M
1995	>$7M	>$1.5M	>$8.5M
1994	>$13.1M	>$1.5M	>$14.6M

*Data from MISREPS and budget estimates

Idealized Process Operation



Conceptual View of Losses

Loss event

- Any action, state, or condition in which a system is not meeting one or more of its design intents
- Includes actual losses and near misses

Characteristics of loss events

- Are unplanned
- Involve a combination of human errors, equipment failures, and/or external events
- Have significant impacts on economics, safety/health, and the environment
- Generally have underlying root causes that create error-likely situations for people and vulnerabilities for equipment
- Frequently preceded by identifiable precursors that can be detected and corrected
- Will always be possible, but can be effectively managed

Effects of loss events

- Less capability
  - inherent capability limitations
  - capability degradation
- Less output
  - quality of products
  - unplanned outages
  - planned outages
- Inefficiency
  - human resource consumption
  - material consumption
  - equipment consumption
  - utility consumption
- Increased liability risk
  - business
  - safety/health
  - environmental

Loss Prevention Iceberg

Loss Prevention Iceberg

Iceberg structure

Top

Small, but critically important area representing major losses. Typically caused by many of the same problems that cause other less severe, but more frequent, day-to-day problems

Visible remainder

Significant area representing the routinely occurring day-to-day problems that lead to safety, environmental, and/or economic losses

Shallow submerged

Another significant area representing abnormal events that almost resulted in losses, but did not for some reason. Generally, these near misses significantly outnumber actual day-to-day losses and can be considered precursors to many of the losses that actually occur

Deeper submerged

Large area representing the various human errors, equipment failures, and external events that cause losses and near misses

Bottom

Large area representing the underlying management system weaknesses that create

- error likely situations for people,
- equipment vulnerabilities, and/or
- inadequate protection against external events.

Perspectives about loss prevention

Corporate management and outsiders

Avoid major losses (or excessive numbers of less severe losses) that threaten business viability and/or lead to significant negative publicity

Day-to-day management

Minimize routine losses that impact productivity and cause management "headaches." Includes some attention to events that almost cause losses (i.e., "near misses")

Buoyancy principle as a guide for loss prevention

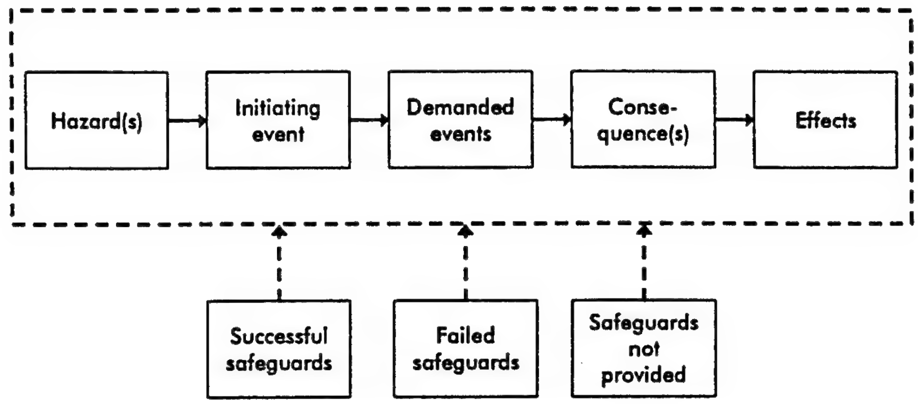
Removing mass from above the water line causes the iceberg to rise

Efforts to address only the visible events help reduce the overall size of the iceberg, but the iceberg will rise in the water and make other events visible

Removing mass from below the water line causes the iceberg to sink

Efforts to address the underlying problems help reduce the overall size of the iceberg and also reduce the number of visible events above the water line

Remember, we generally cannot eliminate all of the iceberg. Even if no visible problems are occurring, danger still exists below the water line. Also, watch out for the potential for major events to break off from the iceberg and appear without warning.



The Accident Sequence: Elements of a Mishap

Hazards — Situations, conditions, characteristics, or properties that create the potential for an undesirable consequence to occur

Initiating event — The event in an accident sequence that, if unmitigated, results in one or more undesirable consequences occurring

Demanded events — One or more events that act (or should have acted) to mitigate the progression of an initiating event toward undesirable outcomes

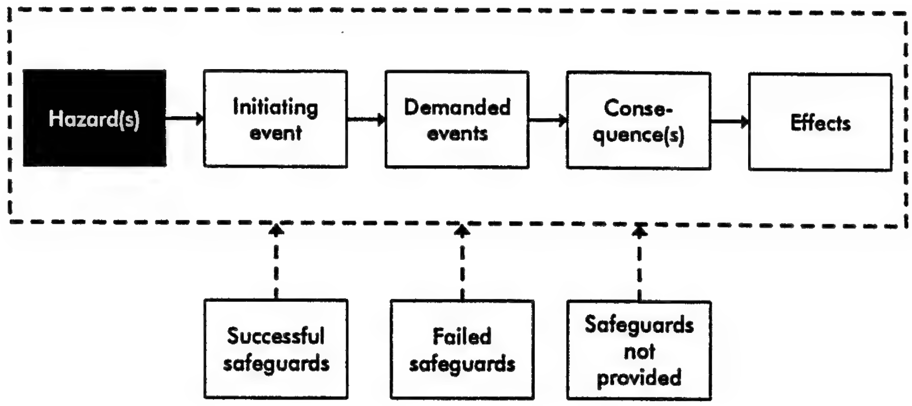
Consequences — Undesirable events having the potential to adversely affect subjects of interest, generally involving the release of energy

Effects — Measurable impacts on subjects of interest within the area of influence of a consequence, generally above some threshold of interest that causes concern

Successful safeguards — Planned protections that successfully act to prevent/mitigate undesirable consequences

Failed safeguards — Planned protections that fail to act as intended to keep hazards from causing undesirable consequences

Safeguards not provided — Reasonable protections that were not provided, but could have acted to keep hazards from causing undesirable consequences



Elements of Mishaps: Hazards

Combustible/flammable hazards

Combustible/flammable hazards exist when there is a potential for one or more materials to rapidly react with an oxidant, releasing energy in the form of heat and light.

Examples
- Hydrocarbons and hydrocarbon derivatives (solids, liquids, and gases)
- Hydrogen
- Other gases (e.g., carbon monoxide)
- Finely powdered nonflammable materials
- Various metals (depending on the oxidizer)

Explosion hazards

Explosion hazards exist when there is a potential for one or more substances to release energy over a short period of time, generating a pressure wave that travels away from the source.

Examples
- Many flammable materials
- Powders and dusts
- Nitrates
- Peroxides
- Highly reactive materials
- Strong oxidizers
- Cryogenic liquids
- Compressed or liquefied gases

Toxic hazards

Toxic hazards exist when there is a potential for one or more materials to cause biological damage to surrounding organisms (through inhalation, ingestion, injection, and/or dermal absorption).

Examples
- Chlorine/bromine
- Cleaning and maintenance fluids
- Contaminated feed, water, and medical supplies

Asphyxiant hazards

Asphyxiant hazards exist when there is a potential for one or more materials to prevent organisms from using available oxygen.

Simple asphyxiants

Simple asphyxiants are typically nontoxic gases that displace and exclude the oxygen from a life–supporting atmosphere. Common simple asphyxiants are carbon dioxide and nitrogen.

Chemical asphyxiants

Chemical asphyxiants are often highly toxic materials that prevent organisms from using oxygen. Carbon monoxide is a chemical asphyxiant that prevents hemoglobin from carrying oxygen.

Corrosion hazards

A corrosion hazard exists when there is a potential for one or more materials to chemically burn body tissues (especially the skin and the eyes) or to excessively erode/dissolve materials of construction or emergency response equipment.

Examples
- Cleaning/maintenance fluids
- Battery acid
- Bleach

Chemical reactant hazards

A chemical reactant hazard exists when there is a potential for one or more materials to chemically combine (or to self-react) and produce undesirable consequences.

Example hazardous chemical reactions
- Upsets involving process temperatures and pressures
- Inadvertent mixing of materials
- Material contamination
- Material handling and storage errors

Thermal hazards

A thermal hazard exists when there is the potential for extreme temperatures to produce undesirable consequences affecting people, materials, equipment, or work areas.

Example causes of hazardous temperature conditions

- Exposed or uninsulated high/low temperature equipment or materials
- Fires or explosions
- Chemical reactions
- Poor ventilation (i.e., inadequate heat dissipation)
- Cooling or heating system failure
- Ambient conditions and other equipment or operations in the area
- Phase changes
- Gas compression or expansion
- Friction

Potential energy hazards

Potential energy hazards exist when undesirable consequences can result from the following:

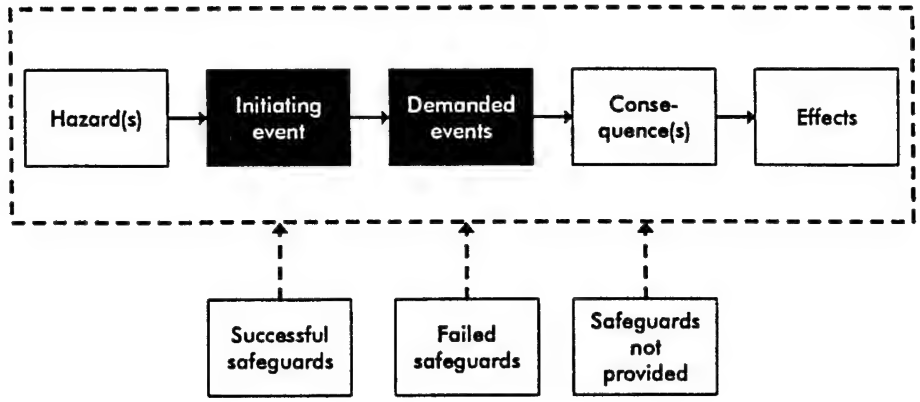
- High pressures (other than explosions) (e.g., normal process pressures)
- Low pressures (e.g., vacuum conditions)
- Mass/gravity/height (e.g., lifting operations)

Kinetic energy hazards

Kinetic energy hazards exist when undesirable consequences can result from linear or rotational motion of process materials, process equipment, support equipment, or vehicles.

Electrical energy hazards

Electrical energy hazards exist when undesirable consequences can result from contact with (or failure of) manufactured or natural sources of electrical voltage or current (e.g., lightning, electrical charges, short circuits, stray currents, and loss of power sources).



Elements of Mishaps: Initiating and Demanded Events

Initiating events

Initiating events can be equipment failures, human mistakes, external influences, or any action/occurrence that places a demand on a safety system.

Examples

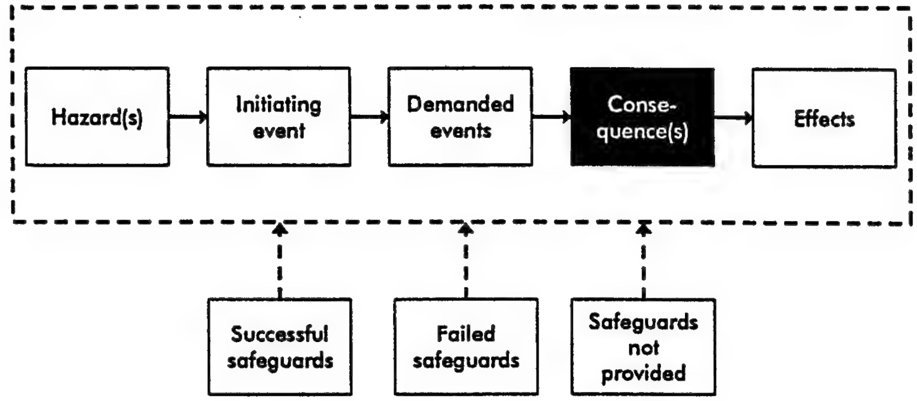
- A rudder breaking
- An engineer setting a control incorrectly
- A rogue wave

Demanded events

Demanded events can be responses to initiating events by equipment and/or humans.

Examples

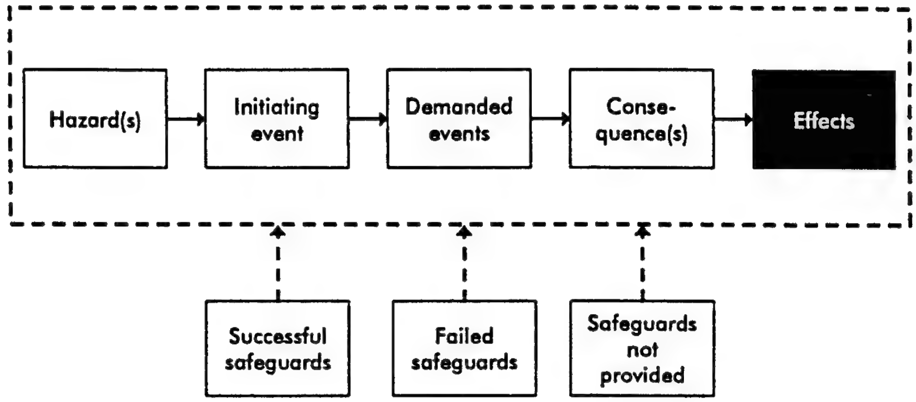
- Relief valve acting to mitigate pressure excursion
- Safety observer interrupting an evolution to correct a safety problem



Elements of Mishaps: Consequences

Summary of mishaps of interest

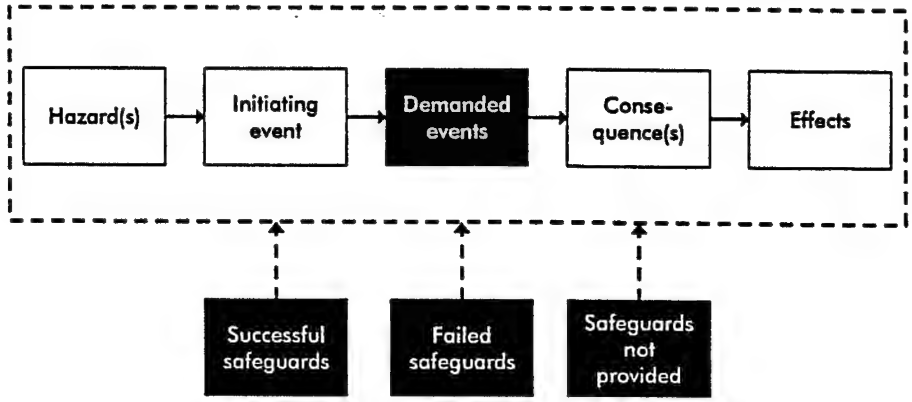
Mishaps of Interest	
Capsizing vessel	Person overboard
Collision with another vessel	Hazardous exposure: contact injury
Collision with a fixed object	Hazardous exposure: toxic/corrosive materials
Collision with a floating object	Hazardous exposure: electrical shock
Grounding vessel	Hazardous exposure: cold environment/ surface/material
Sinking vessel	Hazardous exposure: hot environment/ surface/material
Fouled screw	Hazardous exposure: asphyxiants
Fire/explosion	Hazardous exposure: noise
Firearm discharge	Hazardous exposure: radiation
Equipment damage/loss	Hazardous exposure: biological materials
Loss of small boat	
Loss of helo	
Drowning	



Elements of Mishaps: Effects

Classes of mishaps

Mishap Severity Category	Description
Class A	• The cost of reportable property damage is \$1,000,000 or greater • A vessel is missing or abandoned, recovery is impossible or impractical, the vessel cannot be repaired economically • An injury or illness results in a fatality or permanent total disability • Comparable environmental effects • Comparable mission degradation impacts
Class B	• The resulting cost of reportable property damage is \$200,000 or more but less than \$1,000,000 • Any injury and/or illness results in permanent partial disability • Five or more people are inpatient hospitalized • Comparable environmental effects • Comparable mission degradation impacts
Class C	• The cost of property damage is \$10,000 or more but less than \$200,000 • A nonfatal injury or illness that results in any loss of time from work beyond the day or shift on which it occurred • Comparable environmental effects • Comparable mission degradation impacts
Class D	• The cost of property damage is less than \$10,000 • A nonfatal injury or illness occurs that does not meet the criteria of a Class C mishap • A person is overboard, an accidental firearms discharge occurs, or an electric shock occurs that does not meet the criteria of a higher classification • Comparable environmental effects • Comparable mission degradation impacts



Elements of Mishaps: Safeguards

Safeguards

Safeguards can be engineered systems, personnel monitoring/ response, or administrative policies/programs for (1) lessening hazards, (2) preventing initiating events, (3) preventing adverse demanded events, (4) mitigating consequences, and/or (5) lessening effects.

Examples of safeguards

- Preventive maintenance for the steering system and relief valves
- Policy for having a safety supervisor for all deck operations
- Personnel qualification programs for a key position

Mishap Prevention: Addressing the Causal Factors

- Eliminate hazards
- Prevent initiating events
- Add safeguards
- Make safeguards more reliable
- Reduce consequences
- Reduce effects

Mishap Prevention Concepts

Mishap prevention: addressing the elements of sequences

Eliminate hazards

Make processes inherently safer by *eliminating* hazards

For example:

- Eliminate energy sources:
  - pressure
  - heat
  - potential energy
  - kinetic energy, etc.
- Eliminate the use of hazardous materials and materials that can generate hazardous energy

Prevent initiating events

Reduce the likelihood of initiating events

For example:

- Eliminate error-likely situations that set people up for failure
- Perform inspections, tests, and preventive maintenance as necessary
- Improve design ratings and factors of safety

Add safeguards

Provide "multiple layers of safeguards" in critical applications

For example:

- Add redundant instrumentation, especially those of different design/operation
- Add redundant pumps/blowers, especially those with different types of drivers
- Require additional operator surveillance/checks during operations

Make safeguards more reliable

Reduce the likelihood of safeguard failures

For example:

- Eliminate error-likely situations that set people up for failure
- Perform additional/more frequent inspections, tests, and preventive maintenance
- Improve design ratings and factors of safety
- Staff operations and maintenance departments appropriately

Reduce consequences

Make processes inherently safer by reducing the potential severity of consequences

For example:

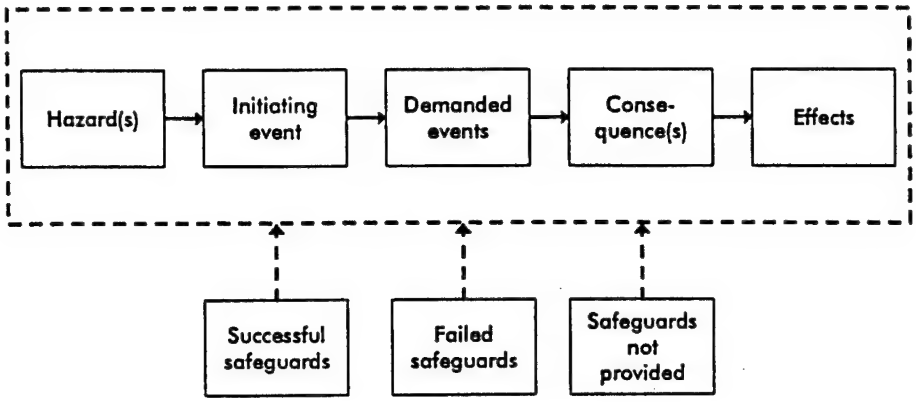
- Reduce energy stored or generated as
  - pressure
  - heat
  - potential energy
  - kinetic energy, etc.
- Minimize inventories of hazardous materials and materials that can generate hazardous energy
- Substitute less hazardous materials for more hazardous materials
- Provide mitigation systems to limit consequences (e.g., alarms, quick-shut-off valves)

Reduce effects

Protect subjects of interest from consequences

For example:

- Provide emergency response training
- Provide personal protective equipment
- Move people away from the danger zones
- Train the employees and community to shelter-in-place



Case Study: The Exxon Valdez Accident

Hazards

- Oil (environmental pollutant/toxin)
- Kinetic energy of vessel

Initiating event

- Ship departed in dark in hazardous conditions (icebergs in normal path, requiring departure from normal course)

Failed safeguards (mitigation)

- Captain not on bridge
- Experienced mate not in charge of critical turn
- First cleanup team did not arrive until 14 hours after spill
  - "dedicated" recovery barge had been in dry dock for repairs for last 2 months
  - booms and skimmer equipment had to be located and loaded onto barge
  - once loaded, barge was unloaded to transport transfer pumps (pumps needed to transfer oil from Exxon Valdez to another ship)
- Dispersants to be used on spill
  - worldwide supply not large enough for this size of spill
  - authorization to use dispersants not given for 3 days
- Response was disorganized because of lack of planning (48 hours after spill, only 3,000 of 240,000 barrels of oil recovered)

Safeguards not provided

- Double hull tanker
  - double hull may not have prevented spill but could have reduced consequences
- Coast Guard monitoring capability

Consequences

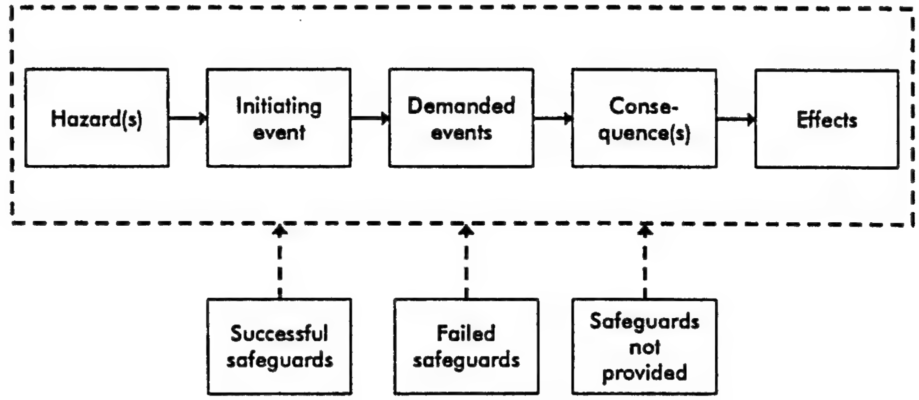
- 600-foot hole ripped in bottom of tanker
- 240,000 barrels (10,000,000 gallons) of oil spilled, posing potentially catastrophic damage to local environment

Effects

- Major environmental damage including many dead animals
  - 1,000+ otters
  - 35,000+ birds
- $1 billion+ in cleanup costs

Long-range impacts

- Environmental damage to Prince William Sound
- Fishing fleet in area affected
- Increased public concern about transportation accidents, especially in ship traffic in Prince William Sound



Case Study: The NASA Challenger Accident

Hazard

- Fire/explosion hazards of fuels (liquid hydrogen and liquid oxygen)

Initiating event

- Liftoff of shuttle (during low ambient temperature)

Failed safeguards

- O-ring failed
  - cold temperature at liftoff reduced pliability of rubber seals
- Ineffective management assessment of identified issues
  - temperature effects on O-ring not well understood (at least by launch safety personnel)
  - no definite operating envelope set for O-rings
  - design specification did not include a temperature range
- Prior evidence of O-ring problems not viewed as a problem
  - O-ring damage observed on 15 of 25 missions
  - eventually, O-ring damage viewed as acceptable

Safeguards not provided

- Effective O-ring design
- Timely communication of temperature limit of O-ring in this service

Consequence

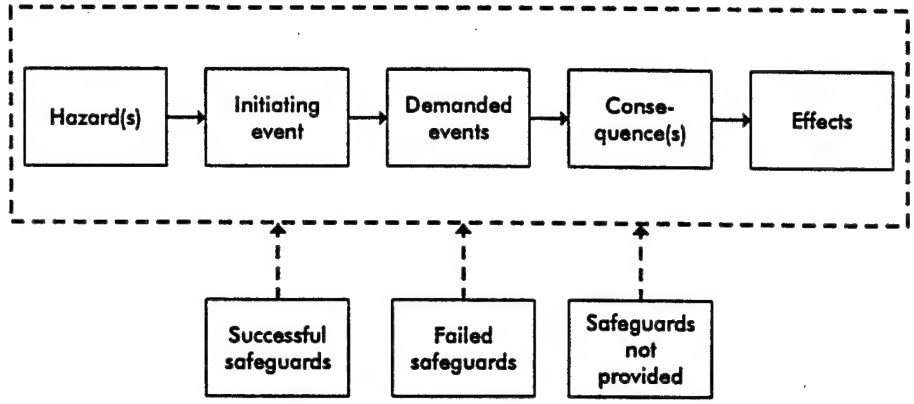
- Flight 51-L explodes 73 seconds after liftoff

Effects

- Loss of seven astronauts
- Loss of multibillion-dollar shuttle

Long-range impacts

- Suspension of shuttle program for almost 3 years
- Safety culture of NASA considered suspect



Case Study: The Union Carbide Bhopal Accident

Hazard

- Principal hazards producing the accident were
  - the reactivity of MIC with water and
  - the extremely toxic properties of MIC

Initiating event

- Introduction of water into the MIC storage tank as a result of
  - theory 1 (Union Carbide) — sabotage
  - theory 2 (Indian government) —
    ✓a slip blind was not used for isolation when a piping section was water washed
    ✓as a result, water flowed through a series of pipes to the MIC tank

Failed safeguards

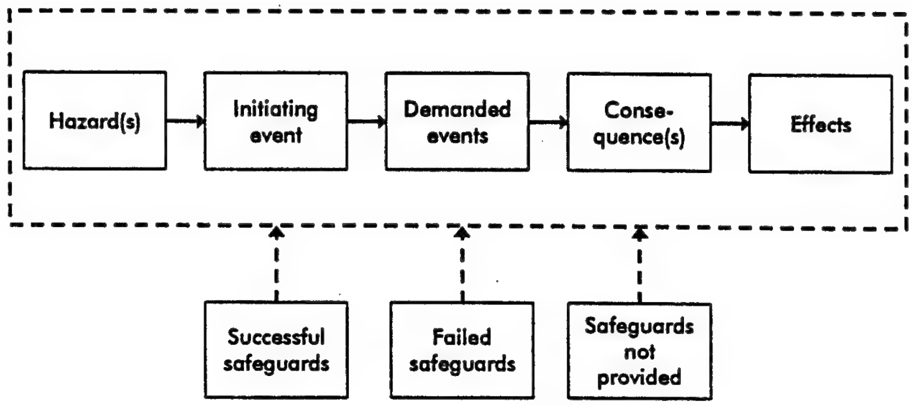
- Refrigeration system associated with the MIC storage tank was out of service
  - refrigerant drained for use in another system
  - system would have reduced the pressure increase in the tank
- Flow to the spare MIC storage tank was blocked, preventing depressurization during the excursion
  - system would have provided surge volume
- Vent gas scrubber was shut down for maintenance
- After scrubber was turned on, fresh caustic was not supplied to neutralize the MIC
  - would have detoxified some of the vapors
- Flare tower was out of service for maintenance
  - would have burned some of the toxic gas
- Evacuation siren not sounded
  - could have provided some evacuation of the population
- Water curtain was not designed to reach heights above 15 m (release occurred 33 m above the ground)
  - would have knocked down some of the vapors
- Security measures against sabotage?

Safeguard not provided
- Inadequate buffer area around plant

Consequence
- Major release of MIC in the plant and into the surrounding community

Effects
- 2,000+ people killed as a result of toxic exposure
- 200,000+ people injured
- $470 million paid by Union Carbide to Indian government
- Costs associated with defending the company against lawsuits
- Reputation damaged in India and the U.S.

Long-range impacts
- Additional inspections of Union Carbide plants in the U.S.
- Major stimulus for worldwide emphasis on process safety, which eventually (along with some other notable events) led to development of OSHA's regulation, *Process Safety Management of Highly Hazardous Chemicals*



Case Study: The Phillips Houston Chemical Complex Accident

Hazards

- Flammable materials (isobutane, ethylene, hexane, and hydrogen)
- High pressure materials

Initiating event

- Clearing of a clog in the settling leg (a daily task that required use of written procedures)

Failed safeguards

- Isolation of the process lines from the environment not provided
  - DEMCO valve did not have its lockout device in place
  - air actuator hose connections for opening and closing the valve were identical (and were switched)
  - safety interlock for valve was not switched to compensate for misconnection of actuator air hoses
  - either the valve was triggered open or an operator jogged the valve full open
  - air supply manual valves for the actuator were open before reattaching the settling leg
- Firewater systems damaged by the explosion

Safeguards not provided

- Redundant isolation of the process from the atmosphere not provided by hardware setup or procedure (still not feasible)
- No means of closing DEMCO valve remotely if the field switch is reversed
- Inadequate separation between the nonprocess buildings (including the control room) and the process equipment, or inadequate construction of the control room
  - control room destroyed by the initial blast

Consequences

- Initial blast equivalent to 1.6 tons of TNT
- Subsequent fires and explosions exposing people and equipment to high heat fluxes, blast effects, and projectiles

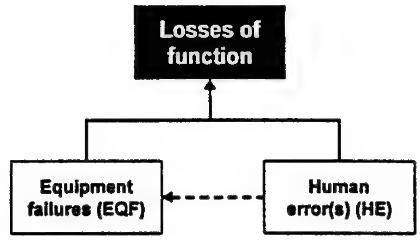
Effects

- 23 fatalities
- 130 injured workers
- Numerous workers affected psychologically
- $750 million in damage to two polyethylene plants and surrounding plants/buildings
- Lost production capability for more than 18 months

Long-range impacts

- Focused regulatory attention on Phillips operations, especially at the Houston Chemical Complex
- Another stimulus for worldwide emphasis on process safety with a direct relationship to acceleration of OSHA's regulation, *Process Safety Management of Highly Hazardous Chemicals*

Events Producing Losses of Function



Events Producing Losses of Function

A specific loss of system function is caused by a combination of one or more equipment failures and/or human errors. (In fact, human errors are also the underlying causes of most equipment failures.) For each loss of system function, there are generally many combinations of events that can produce the performance problem

Combinations of events producing a loss of function

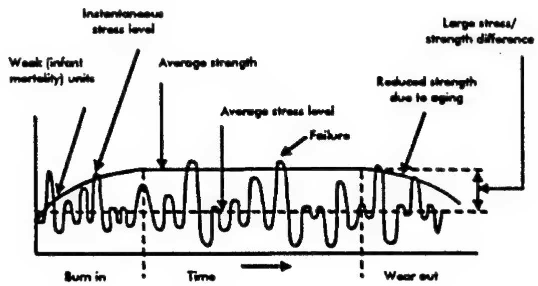
- EQF #1
- EQF #2, EQF #3
- HE A, HE B
- EQF #4, HE C
- HE A, HE C, HE D
- Etc.

Example

A lighting system has a single power supply and two light bulbs in parallel. The entire circuit is protected by a single breaker and controlled by a single switch. The following is a list of events contributing to a lack of room lighting:

- Power supply fails off
- Wiring failure
- Circuit breaker fails open
- Switch fails open
- Operator inadvertently opens switch
- Light bulb #1 fails off; light bulb #2 fails off
- Operator incorrectly installs light bulb #1; operator incorrectly installs light bulb #2
- Operator incorrectly installs light bulb #1; light bulb #2 fails off
- Light bulb #1 fails off; operator incorrectly installs light bulb #2

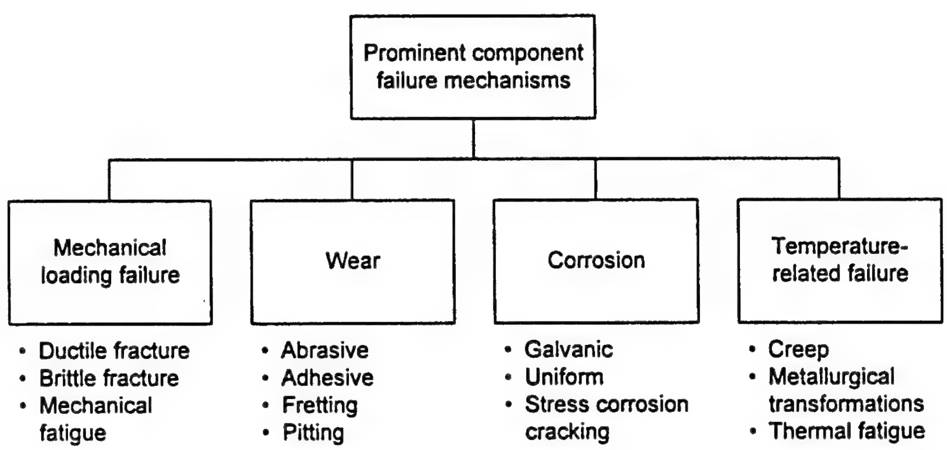
Stress vs. Strength Distributions



Equipment Life Periods

An equipment failure is a state or condition in which a component no longer satisfies some aspect of its design intent.

Equipment failure occurs when the "stress" on the component exceeds the component's "stress resistance." (In this case, "stress" refers to some negative influence, and "stress resistance" refers to the component's resistance to that influence.)



Some important properties of metals providing "stress resistance"

Ductility	The ability to deform plastically without fracturing
Toughness	The ability to absorb energy before fracturing
Fatigue resistance	The ability to withstand repeated application of load without failing
Hardness	The ability to resist (1) local penetration and (2) wear
Chemical resistance	The ability to resist chemically reacting with compounds in process materials, the environment, and/or other materials of construction
Creep resistance	The ability to resist plastic deformation under sustained load

Causes of Component Failures

- Faulty design
- Faulty material
- Improper fabrication
- Incorrect construction
- Misoperation
- Inadequate maintenance

Causes of Component Failure

Faulty design
- Incorrect equipment sizing
- Improper material specified
- Weld joints in regions of high stress
- Structural discontinuities, notches, etc.
- Etc.

Faulty material
- Material chemistry out of specification
- Improper heat treatment
- Etc.

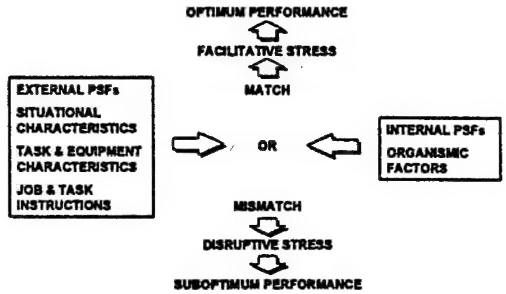
Improper fabrication
- Improper materials used
- Improper welding
- Incorrect machining tolerance
- Improper stress relief
- Etc.

Incorrect construction
- Improper mounting
- Component misalignment
- Improper welding
- Bolts improperly torqued
- Use of incorrect cleaning fluids
- Etc.

Misoperation
- Improper startup
- Operating outside safe design limits
- Severe service conditions
- Etc.

Inadequate maintenance
- Repairs performed incorrectly
- Unsuitable replacement parts
- Preventive maintenance not performed
- Etc.

Relationship of PSF's and Human Performance



Human Error

Human error is an intentional or unintentional action (or inaction) that is outside of the prescribed course of action. Human error is often the dominant contributor to system failures and is generally the underlying problem even when equipment failures play a significant role in system failures.

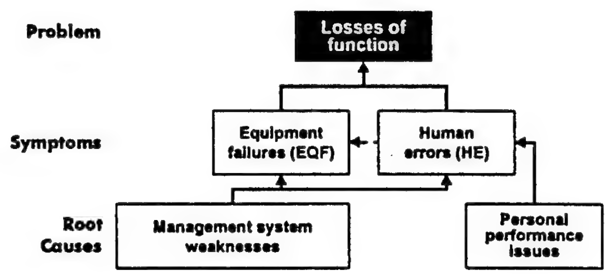
System failures resulting directly from human errors

Missiles	20 to 53%
Nuclear weapons	28 to 82%
Electronic systems	23 to 45%
Aircraft	60 to 90%
Nuclear power	70 to 80%
Petrochemical	65 to 90%

Human performance is strongly influenced by performance shaping factors (PSFs), which include the following:

External PSFs	Situational characteristics Task/equipment characteristics Job/task instructions
Stressor PSFs	Psychological stressors Physiological stressors
Internal PSFs	Organismic factors

Events Producing Losses of Function

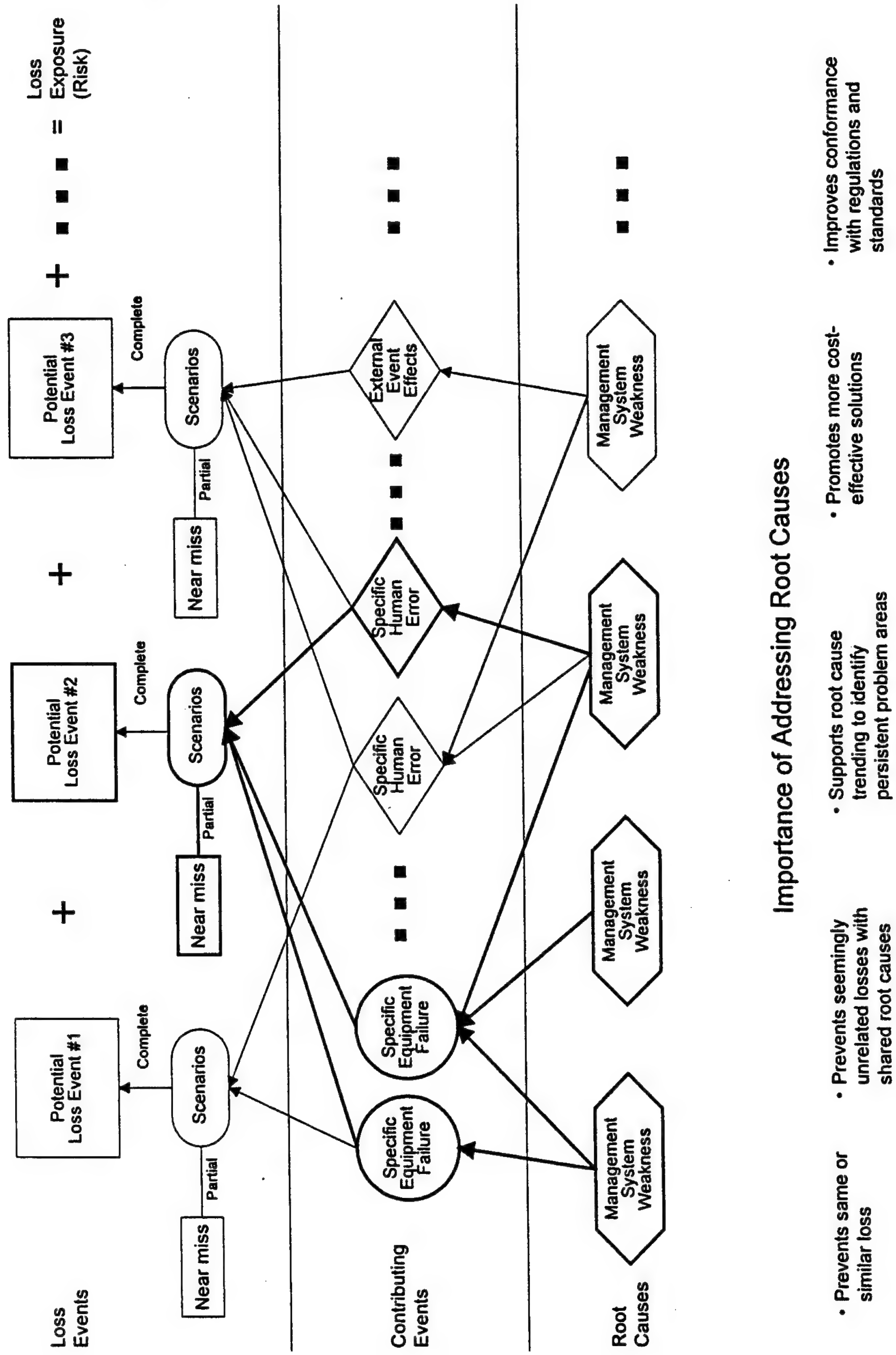


Introduction to Root Causes

Root cause definition

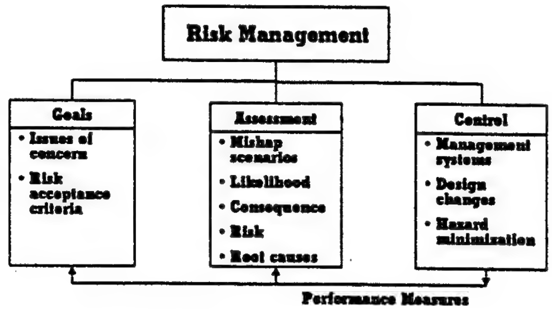
- The most basic causes of an event that
  - can be reasonably identified and
  - management has control/influence to fix
- Typically, root causes are the absence, neglect, or deficiencies of management systems that control human actions and equipment performance

This diagram illustrates how management system weaknesses lead to human errors, equipment failures, and adverse effects from external events that combine to produce losses. Note that each management system weakness may influence more than one human error, equipment failure, or external event.



United States Coast Guard
IRA Manual

Section 2
Managing Risk



Risk Management

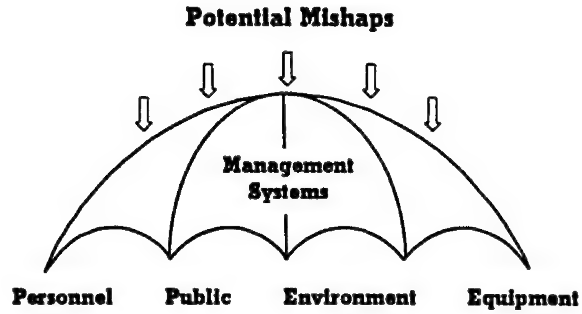
Inherent in every process or operation are hazards that, if not properly controlled, could cause harm to the public, organizational personnel, the environment, and organizational operations. To effectively and properly manage the risks associated with these hazards, management must:

Set risk management goals — that define the issues of concern to the organization and establish criteria for accepting (or reducing) the level of risk inherent in its operations

Assess the risk associated with operations — to systematically identify potential operational failures, determine if such failures result in issues of concern, and evaluate the likelihoods and/or consequences of failures that are of concern. Assess the risk of such failures and institute additional control measures when the risk is not acceptable

Control the unacceptable risks — by revising or instituting management systems, redesigning equipment (e.g., adding redundancy), or minimizing the hazard (e.g., switching to a nonflammable solvent for cleaning parts) to bring the risk to an acceptable level

Measure the performance of operations — to determine whether control measures in place are keeping risk at an acceptable level. If the risk level is unacceptable, management will need to determine if (1) their risk management goals are too stringent, (2) more detailed assessments are needed to identify root causes, and/or (3) additional controls are needed



Risk Umbrella

To control risks, organizations develop an umbrella of management systems that protect personnel, the public, the environment, and equipment from potential mishaps. As issues of concern expand for an organization, the umbrella of management systems may need to be expanded to cover these new concerns. As risk acceptance goals change, the "toughness" (or strength of protection) provided by the umbrella must change to provide acceptable protection. In other words, organizations must establish risk goals that define what to protect and how well to protect it.

The risk umbrella is not perfect. The umbrella is not large enough to protect against all potential mishaps. And the umbrella is not thick enough to prevent all mishaps from breaking through it. An organization's risk goals define the size and strength of its umbrella of protection.

Risk Goals

Risk Goals

It is difficult to assess or control risks without knowing what to aim at (i.e., having a target) and how closely you hit the target. Thus, the first element of risk management involves establishing risk management goals.

Issues of concern

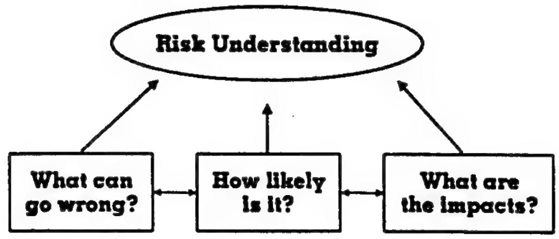
Issues of concern are consequences that have a significant impact on the organization. Both the type of consequence (personnel safety, equipment damage, public safety, operation failure, etc.) and the level of the consequence (minor, moderate, major, etc.) are factors that management must weigh in defining issues of concern.

Risk acceptance criteria

All operations in a organization pose some risk. In order to determine whether operations are adequately controlled, management must establish some type of risk acceptance criteria. The criteria usually take the form of a likelihood level, a consequence severity, or a combination of these two, that should not be exceeded. A potential system failure that results in exceeding these criteria generally results in recommendations to better control the risks.

Example issues of concern

Issue	Consequence Type	Severity
Safety	Personnel safety Public safety	Fatality or multiple injury Multiple injury
Environmental	Onsite spill/release Offsite spill/release	Cleanup required EPA reportable
Equipment	Operational outage Major failure	Delay > 2 hours Repair/replacement > $10,000
Media	Operational failure Safety/environmental issue	National broadcast Multiple-city broadcast



Understanding Risk

What can go wrong?

Systematic hazard analysis methods are used to identify system/ operational failures (due to equipment failures, human errors, and/or external events) that create issues of concern. Based on the number and types of failures that must occur, an analyst gains a good understanding of the risk associated with an issue of concern.

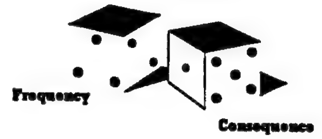
How likely is it?

Likelihood is usually expressed as the probability or frequency of a mishap occurring. If the likelihood is low enough, analysts may dismiss a potential mishap scenario as not credible, not of concern, or of extremely low risk. Note, however, that the likelihood cutoff for making such judgments often changes with the type and severity of consequence associated with the potential mishap.

What are the impacts?

A mishap can impact many areas of concern with different degrees of severity. For example, a fired heater that is lit without proper purging could explode, probably causing major equipment damage and personnel injury. However, it is unlikely that this mishap causes environmental damage or public injury. The type and severity of consequences associated with a mishap scenario help an analyst to further understand and judge risk.

Risk



- Risk is the doublet of frequency (F) and consequence (C), often expressed as F x C
- Two categories of risk
  - risks that can be minimized or eliminated
  - residual risks

Frequency

The frequency of a mishap scenario is usually expressed as events per year. The frequency should be determined from historical data if a significant number of events have occurred in the past. Usually, however, we focus on mishaps with more severe consequences for which little historical data exists. For such events, the mishap frequency is calculated with basic data from industrial databases.

Consequence

Consequence is expressed as the number of people affected (injured or killed), area affected, outage time, mission delay, dollars lost, etc. Because a single mishap scenario can have a range of consequences, we normally use categories or best estimates to define the outcome of a mishap.

Risk

The risk of a mishap is calculated as the product of the frequency and consequence of the mishap. By doing this, we are able to compare the risks of various operations and different mishaps that can occur within an operation. However, you should also compare the two consequences since we often judge risk based on consequence alone.

For example, suppose mishap #1 has a frequency of 10^{-2}/yr and a consequence of $10,000. Mishap #2 has a frequency of 10^{-4}/yr and a consequence of $1,000,000. The risk of either mishap is $100/yr, but you might self-insure for accident #1 and buy insurance for mishap #2 — different decisions based on consequence.

Risk Categories

There are risks with any operation. Once these risks are known, we can take measures to reduce the risk (e.g., insulate hot surfaces to reduce the chance of getting burned) or eliminate the risk (e.g., switching to nonflammable cleaning materials to eliminate a fire hazard). However, some known risks are accepted as the "cost of doing business." These residual risks should be within an organization's risk acceptance criteria.

Risk Acceptance

Many factors influence our acceptance of risk:

- Familiarity
- Likelihood
- Control
- Media attention
- Consequence
- Suddenness of consequence
- Personal vs. societal
- Benefit
- Dread

Risk Acceptance

Many factors influence our acceptance of risk:

Familiarity — People are more comfortable and accepting of risk when they are personally very familiar with the operation. (For example, is a traveler more fearful of a bus accident or a plane crash? Which has the greater risk?)

Likelihood — Our belief in the likelihood or credibility of a mishap influences our risk acceptance.

Control — We accept more risk when we are personally in control because we trust ourselves. (For example, are you more afraid when you drive a car too fast or when you are the passenger in a speeding car?)

Media attention — We fear problems that we are aware of and that we perceive are important and credible. Media coverage of issues increases our awareness and belief in the credibility of a problem.

Consequence — Our risk acceptance level is low for facilities that can have mishaps with large consequences. For example, a severe accident at a nuclear power plant could affect a large population. Thus, we build very few such plants and we highly regulate their safety. The risk associated with coal-fired plants is higher, but such plants are not as regulated by the government.

Suddenness of consequence — The sooner we feel the impact of an event, the less likely we are to accept the risk. (Will you risk your life to save your car from a carjacker? Will you risk your life by smoking cigarettes for 40 years?)

Personal vs. societal — We accept risk that only affects ourselves. We apply a higher standard to protect society.

Benefit — As the benefit we derive from an operation increases, we are more accepting of the risk. For example, driving a car is more risky than traveling by plane. Because of personal benefit, people are usually more accepting of driving than flying.

Acceptable Risk

- There is no practical definition
- Its perception varies among industries
- It is very hazard specific
- Even government agencies are not consistent
- There are contemporary comparisons that can be made

Acceptable Risk

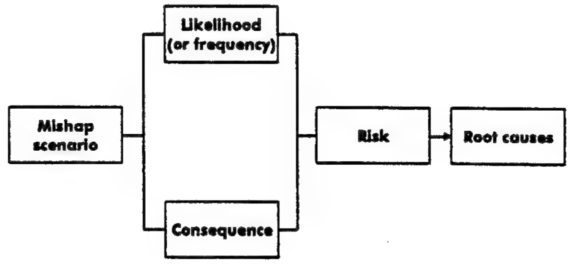
With the many different factors that influence our ideas and acceptance of risk, it is nearly impossible for us to define an acceptable risk level. Many companies and the government have, directly or indirectly, defined acceptable risk. However, this definition has varied dramatically among industry, government agencies, and even hazardous items (e.g., What risk is acceptable with the carcinogens benzene in gasoline and asbestos in public buildings?). Even with these difficulties in defining acceptable risk, we should not give up on the idea. By setting a risk standard, organizations can more easily identify high risk operations, allocate resources more appropriately, and measure the effectiveness of their risk reduction efforts.

The following table is a summary of implied risk acceptance criteria from various government agencies for various substances. The numbers listed are no longer valid, but do illustrate that acceptable risk is difficult to determine.

Agency Interpretations of Significant Risk

Lifetime individual risks that agencies chose to regulate

Risk	*Substance (statute)*
4×10^{-1}	Arsenic (OSHA)
2×10^{-1}	Ethylene dibromide (OSHA)
1×10^{-1}	Ethylene oxide (OSHA)
6×10^{-2}	Asbestos (OSHA)
3×10^{-2}	Arsenic from primary copper smelting (CAA)
2×10^{-2}	Coke oven emissions (CAA)
1×10^{-2}	Methylenedianiline (TSCA)
1×10^{-2}	Butadiene (TSCA)
1×10^{-2}	Uranium mines (CAA)
5×10^{-3}	Benzene from coke ovens (CAA)
2×10^{-3}	Benzene from fugitive emissions (CAA)
1×10^{-3}	Radionuclides from phosphate mines (CAA)
8×10^{-4}	Arsenic from glass manufacture (CAA)
8×10^{-4}	Radionuclides from DOE installations (CAA)
2×10^{-4}	Workers in coke ovens (OSHA)
1×10^{-4}	Radionuclides from NRC licensees (CAA)



Risk Assessment

The risk assessment process begins with the development of mishap scenarios for an operation that can result in issues of concern. Once the mishap scenarios are known, we must determine whether the risks of these scenarios are acceptable. Thus, we must determine the likelihood and consequence of each scenario. The product of these two factors, summed for all mishap scenarios identified, gives the risk of the operation. With the risk known, management can now initiate actions to investigate the risks that are unacceptable (root cause analysis) and establish appropriate controls.

Mishap scenario — a combination of events, including initiating events, (equipment failures, human errors, external events) and failed safeguards (equipment failures and human errors) that result in an undesirable consequence (an issue of concern). Coarse hazard analysis methods are often used to systematically identify mishap scenarios for an operation

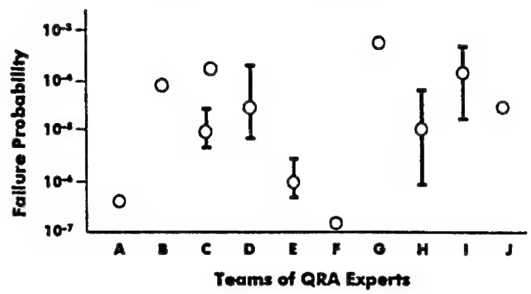
Likelihood — the frequency or probability that a mishap scenario occurs. This value is usually estimated by multiplying the frequency of a mishap initiating event and the failure probabilities of safeguards (hardware and administrative controls) that should have "stopped" the mishap

Consequence — the damage associated with the mishap scenario. Numerous analysis tools and computer models are available to calculate the damage caused by a mishap scenario

Risk — the product of mishap scenario frequency and consequences

Root cause — the underlying, basic reason *why* a failure occurred. Using the risk assessment results, we focus on those failures that contribute to the highest risk mishaps. We then use structured investigation tools to find the root causes of these specific failures and focus management efforts on fixing these root causes

Influence of Assumptions



Influence of Assumptions

In performing or evaluating risk assessments, you should pay careful attention to any assumptions made during the identification of mishap scenarios and estimation of mishap likelihoods and consequences. The above graph shows the results of a benchmark study in which several teams of risk experts calculated the failure probability of a system. All the experts were given the same system design and the same failure data for the system components. The large variability in answers (almost four orders of magnitude) was attributed to the different assumptions the experts made.

Risk Characterization Methods

- Quantitative
  - point estimates
  - categorization
- Qualitative

Risk Characterization Methods

Risk assessment involves processing a large quantity of data. Often hundreds or even thousands of mishap scenarios must be evaluated to estimate the risk of an operation. Thus, an analyst should consider the level of detail needed in risk results in order to make decisions prior to starting the risk assessment process. Qualitative methods as well as coarse and detailed quantitative methods exist for characterizing risk results. When trying to get the big picture and identify general areas/operations where higher risk exists, qualitative methods may suffice. When comparing two competing design alternatives with different strengths and weaknesses, a more detailed risk assessment may be needed to see the impact of the different designs.

The following are examples of risk assessment results in four different categories.

Absolute frequency estimates

- The expected frequency of plant explosions is 5×10^{-4} per year
- We expect that four large toxic releases will occur during the lifetime of this facility
- The probability of a large release of chlorine sometime during a 1-year period is 2×10^{-3}
- The probability of a safety system failure is 4×10^{-4} per batch
- We expect to see, on the average, one small fire every month in this process building
- The mean time between runaway reactions in this reactor is 1,000 years

Absolute consequence estimates

- This mishap will seriously injure 50 people because of blast overpressure and thermal radiation effects
- If this event occurs, we expect the process to sustain $2 million in equipment loss and 3 months of downtime
- The maximum downwind center line concentration of HF beyond the plant boundary will be 500 ppm, given that the release occurs

- If the reactor detonates, we estimate that 20 employee fatalities will occur and 50 members of the public will be hurt
- The toxic plume is expected to extend 4,000 meters downwind at concentrations above the short-term exposure limit (STEL)
- The results indicate that 2,000 people will be exposed to a concentration of ammonia greater than the emergency response planning guideline concentration (e.g., ERPG-2)
- If the pipe breaks, we expect a 100-kg-per-second release of butane into the diked area
- The maximum distance that a 1-psi overpressure will be felt is 500 meters

Absolute risk estimates

- The risk to employees from this process is 5 x 10^{-4} expected fatalities per year
- The annual economic risk of operating this unit is $1 million because of fire and explosion accidents
- This analysis shows that less than 1 injury per year is expected, but the frequency of injuring 1,000 or more people is once every 5,000 years
- We calculate the frequency of mishap A as once every 5 years and mishap B as once every 1,000 years
- The total loss if A occurs will be $200 million
- The risk of A and B are the same — $200,000 per year

Relative risk estimates

- The risk from Process A is about 15 times greater than the risk from Process B
- If design changes 1 and 2 are made and operating procedure A is modified, then the risk of operating the unloading facility can be reduced by a factor of 30
- The major risk contributor in this process is failure of safety system C. Its failure contributes to 50% of the risk of this process
- The estimated risk of a worker fatality during this operation is 1,000 times smaller than the risk to an average individual from driving a car to work once

Point Estimate Risk Characterization

$$Risk_{\substack{Mishap \\ scenario}} = F_{\substack{Mishap \\ scenario}} \times C_{\substack{Mishap \\ scenario}}$$

where

$$F_{\substack{Mishap \\ scenario}} = F_{\substack{Initiating \\ event}} \times \prod P_{\substack{Safeguards \\ being \\ undependable}}$$

and

F = frequency of occurrence
C = consequence
P = probability of occurrence

Point Estimate Risk Characterization

Mishap Risk Calculation (Cost = $10,000)

Scenarios	Initiating Event		Failed Safeguards				Scenario Frequencies
Scenario 1	A		B		C		
	1/y	x	0.1	x	0.01	=	0.001/y
Scenario 2	D		F		G		
	0.1/y	x	0.1	x	0.1	=	0.001/y
Scenario 3	E		B				
	0.1/y	x	0.1			=	0.01/y
					F_{mishap}	=	0.012/y

Risk = 0.012/y x $10,000 = $120/y

As you can see, we identified three scenarios that could cause this particular mishap, which has an associated consequence of $10,000. The mishap frequency is the sum of the scenario frequencies. Knowing the mishap frequency, consequence, and risk, management can now determine if the mishap risk is acceptable. If not, these same results help us focus on where additional control efforts may be needed. The importance of safeguard B in this example is about 93%. By finding and fixing the root causes of safeguard B's failure, we can significantly reduce the risk of this mishap and perhaps others.

Observations — Point Risk Estimate

- Very precise
- Accuracy depends on accuracy of scenario models and specific likelihood/ consequence data for each event
- Very resource intensive to use in detailed studies
- Can provide all types of risk-based information in a variety of presentation formats

Observations About Point Risk Estimates

As one can see from the example, characterizing risk with point estimates provides very precise answers. However, this "preciseness" can be misleading because there are often large uncertainties associated with the data used in these calculations. If you are comparing alternatives and the point estimates of risk are close, you probably should consider other factors (ease of maintenance, amount of operator training required, etc.) in making a selection.

We also note that the point estimate risk method is resource intensive and calculation intensive. If you do not have the people and skills to use this method, alternate risk estimates should be used.

Risk Characterization Using Categorization

- Define likelihood and consequence categories
- Establish appropriate risk priorities
- Identify potential mishap scenarios
- Assign a likelihood and consequence category
- Use the likelihood/consequence category to assign a risk priority

Risk Characterization Using Categorization

- Define likelihood and consequence categories for evaluating scenarios
- Assign appropriate risk acceptance levels to each likelihood/ consequence combination using a risk matrix or numerical equation
- Identify potential mishap scenarios using structured hazard analysis techniques
- Assign a likelihood and consequence category for each outcome of each scenario
- Use the combination likelihood/consequence category for each scenario to assign a risk acceptance level to the scenario

The risk assessment process changes very little if risk is to be characterized using categories versus point estimates. In this case, the analyst must (1) define likelihood and consequence categories to be used in evaluating mishap scenario risk acceptability and (2) define the level of risk associated with each likelihood/consequence category combination. In defining categories, you must provide enough categories so that meaningful results are obtained, but not so many categories that analysis teams have difficulty assigning category values to scenarios.

For example, using too few categories may lead to analysts assigning all the mishap scenarios to the same risk level. Very little is learned in the risk assessment process and no direction is given as to where to focus management controls. Too many categories, on the other hand, will consume excessive amounts of the analysis team's time in determining the "right" category assignment for each mishap scenario.

Frequency and consequence categories can be developed in a qualitative or quantitative manner. Qualitative schemes (i.e., low, medium, high) typically use qualitative criteria and examples of each category to ensure consistent event classification. Multiple consequence classification criteria may be required to address safety, environmental, operability, and other types of consequences. The following tables are the basis for a scenario-based risk categorization system used in the hydrocarbon processing industry.

Example criteria for safety consequences

Consequence	Consequence
Low	A toxic chemical release is expected to move into the surrounding environment in negligible concentrations. Injuries and illnesses are unlikely unless the exposure is over an extended period of time, and the injuries and illnesses would likely be limited to first aid cases
Low to Medium	A toxic chemical release is expected to move into the surrounding environment in concentrations sufficient to cause injuries and illnesses unless prompt corrective action is taken. Should injuries and illnesses occur, some recordable cases could be expected If hydrocarbon is released, the release rate is such that a moderate amount of hydrocarbon (in the range of a few hundred pounds) would be released in a few minutes. Should ignition occur and result in an explosion or fire, some personnel may have recordable injuries
Medium to High	A toxic chemical release is expected to move into the surrounding environment in concentrations that could result in injuries and illnesses to people inside and outside the facility If hydrocarbon is released, the release rate is such that a significant amount of hydrocarbon (in the range of 2,000 to 10,000 pounds) would be released in a few minutes. Should ignition occur and result in an explosion or fire, some personnel may be seriously injured
High	A toxic chemical release is expected to move into the surrounding environment in concentrations that are life threatening. A large number of people inside and outside the facility are likely to be seriously injured or become seriously ill If hydrocarbon is released, the release rate is such that more than 10,000 pounds of hydrocarbon is released in a few minutes, forming a vapor cloud that, if ignited, could result in a major explosion and fire with serious injuries to personnel

Example criteria for likelihood

Likelihood*	Consequence
Low	The accident scenario is considered highly unlikely. The probability is very low (< 3%)
Low to Medium	The accident scenario is considered unlikely. It could happen, but it would be surprising if it did. The probability is low (in the range of 3 to 30%)
Medium to High	The accident scenario might occur. It would not be too surprising if it did. The probability is in the range of 30 to 90%
High	The accident scenario has occurred in the past and/or is expected to occur in the future. The probability is greater than 90%

*Likelihood assessments are for the remaining life of the unit, assuming normal maintenance and repair

Example risk matrix

Likelihood of Occurrence \ Severity of Consequence	Low	Low to Med.	Med. to High	High
High	A	M	U	U
Med. to High	A	A	U	U
Low to Med.	A	A	M	U
Low	A	A	A	M

A = acceptable
M = marginal
U = unacceptable

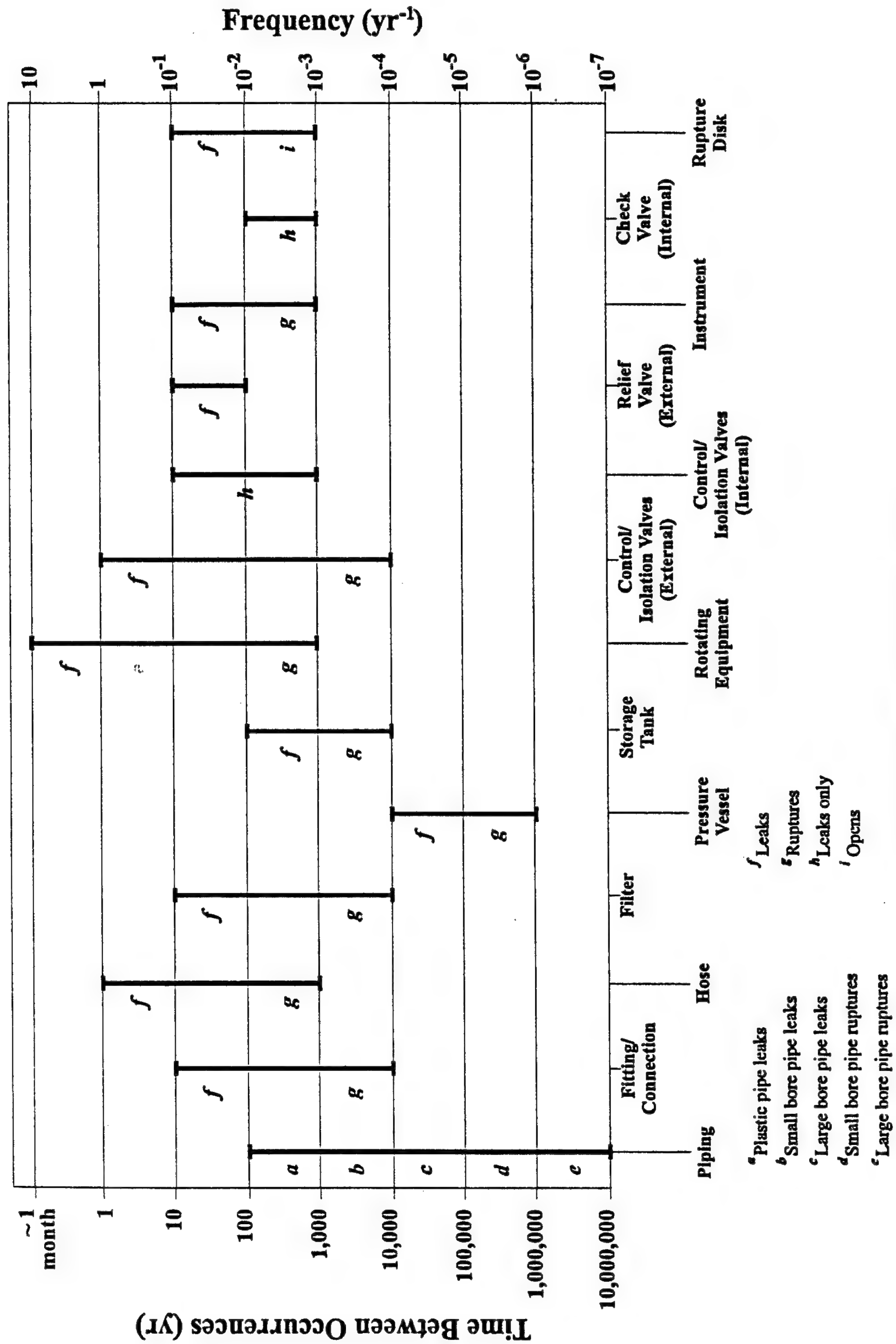
Summary table of scenarios, risk, and recommendations

Ref. No.	Scenarios Considered	Risk Associated with Scenario Likelihood/Consequence		Scenarios Considered
		Before	After	
1	Hydrocarbon contamination of the cooling water system	**Unacceptable** Frequency: MH Consequence: MH	**Acceptable** Frequency: L Consequence: MH	Ensure that the debutanizer bottoms coolers, the debutanizer tops condensers, the lean oil cooler, the depropanizer tops condensers, and the sponge oil cooler are classified as class A exchangers for inspection purposes Replace the tube bundles in these exchangers with stainless steel bundles
2	Light material in the bottoms stream from the debutanizer column	**Unacceptable** Frequency: LM Consequence: MH	**Acceptable** Frequency: L Consequence: MH	Review and if necessary upgrade the overpressure protection on the deisohexanizers and the gasoline treaters Install a shutoff valve in the lean oil line to the hydrogen absorber; the valve should automatically close on low flow in the line
3	Relief valves open on the upper column because of water carry-over from the desalters	**Marginal** Frequency: H Consequence: LM	**Acceptable** Frequency: LM Consequence: LM	Continue with present program to prevent bottom sediment and water from entering the unit, including the planned installation of the on-line water analyzers Install more reliable indications of a loss of mixer function at the crude storage tank
4	High temperature in the regenerator, the regenerator overhead lines from the top of the regenerator to the secondary cyclones, and the CO (80-inch duct) line from the secondary cyclones to the CO heater	**Unacceptable** Frequency: H Consequence: MH	**Marginal** Frequency: LM Consequence: MH	Install a low catalyst level alarm on the regenerator and install a switch that will close the regenerated catalyst slide valves on low-low regenerator catalyst level Install an automatic switch to stop the flow of torch oil to the regenerator during a feed diversion Install instrumentation to automatically stop the slurry to the reactor risers Use condensate instead of sour water for the normal and emergency sprays in the regenerator and the regenerator overhead lines

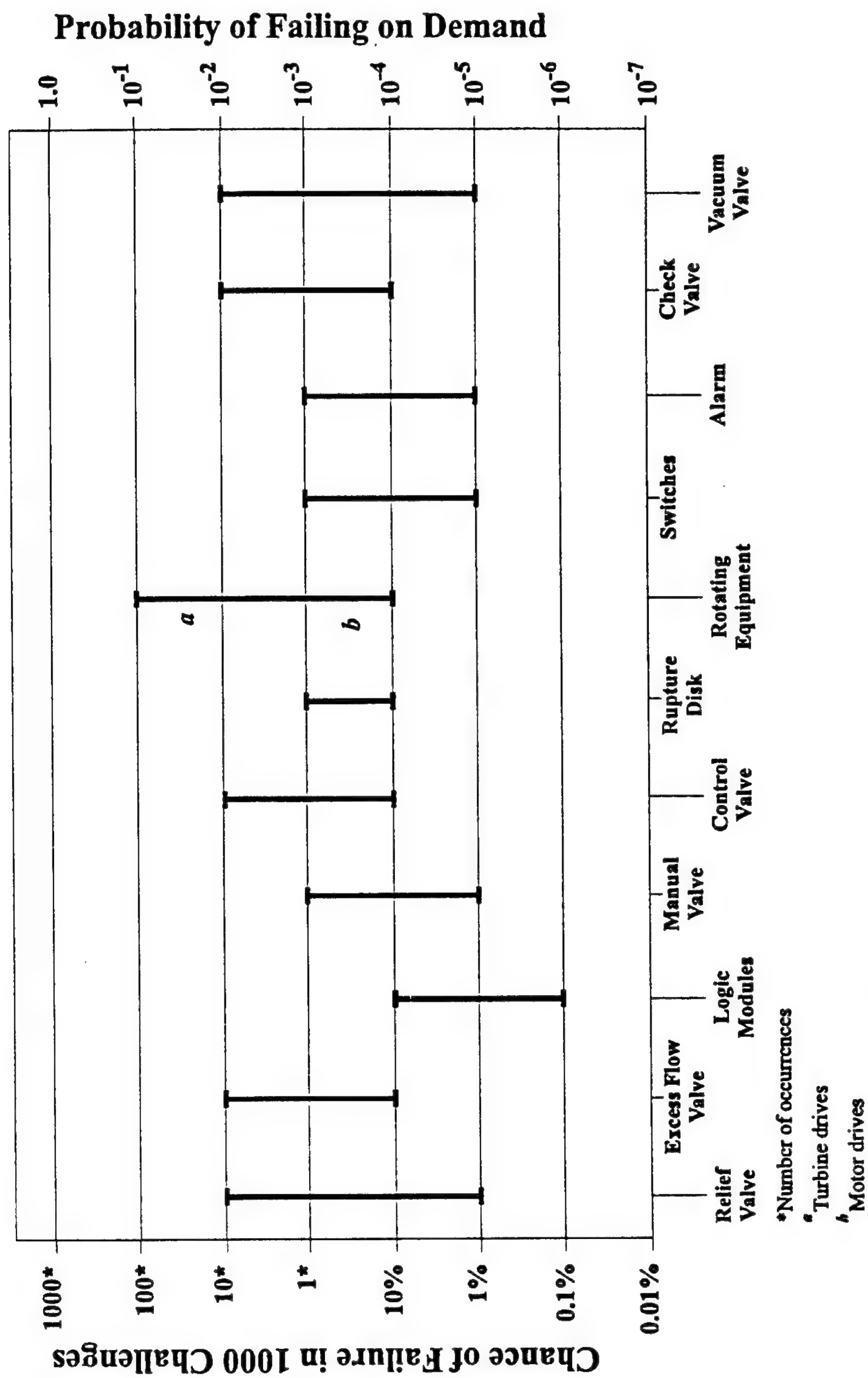
The qualitative scheme shown above can easily be converted to a quantitative scheme by assigning numerical values to each category in the classification criteria and risk matrix. This approach allows the same criteria and matrix to be used for qualitative and quantitative analyses.

In developing quantitative frequency and consequence categories, it is a good idea to let the size of the categories change proportionately. For example, if the frequency categories change by factors of 10, then the consequence categories should also change by factors of 10. Since risk is the product of these two factors, keeping the category changes proportional will help keep risk estimates proportionally consistent.

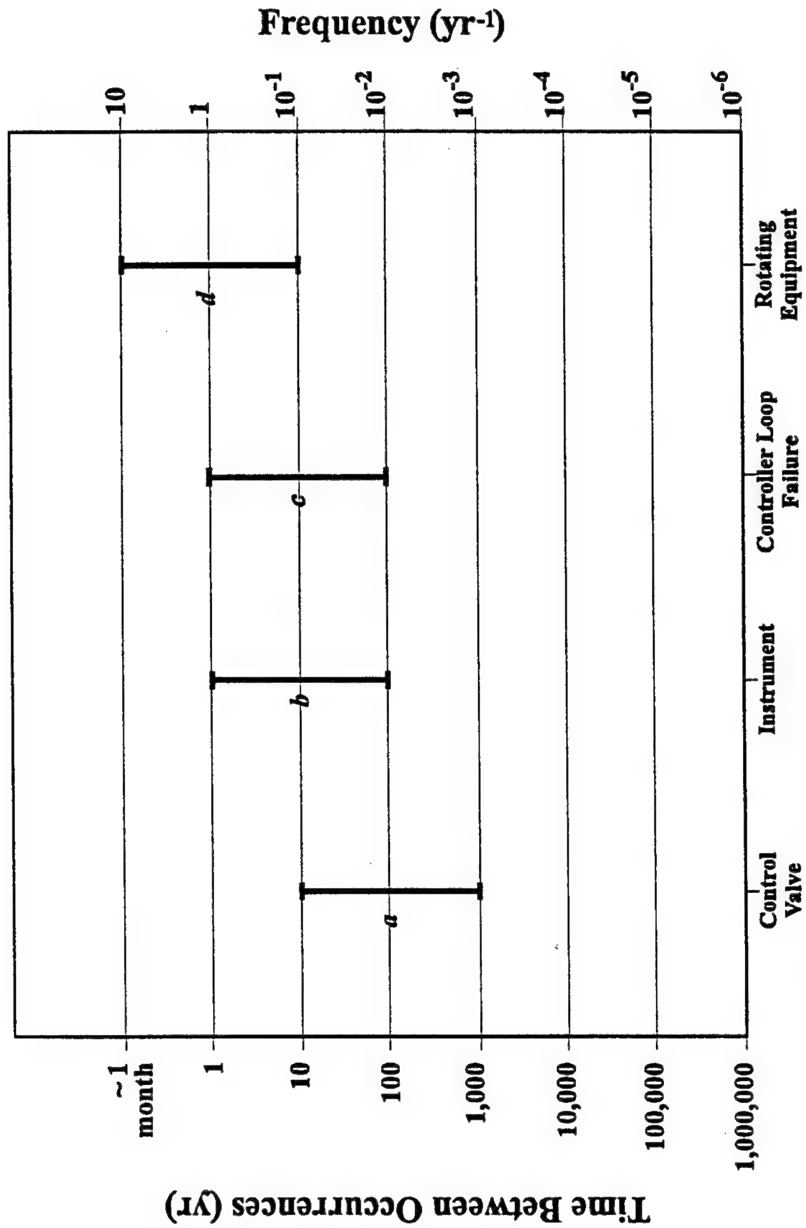
The next five figures depict common frequency and probability ranges for numerous types of equipment failures, human errors, etc. These can be used to assist in the development of qualitative and quantitative risk categories.



Common Loss of Containment Events

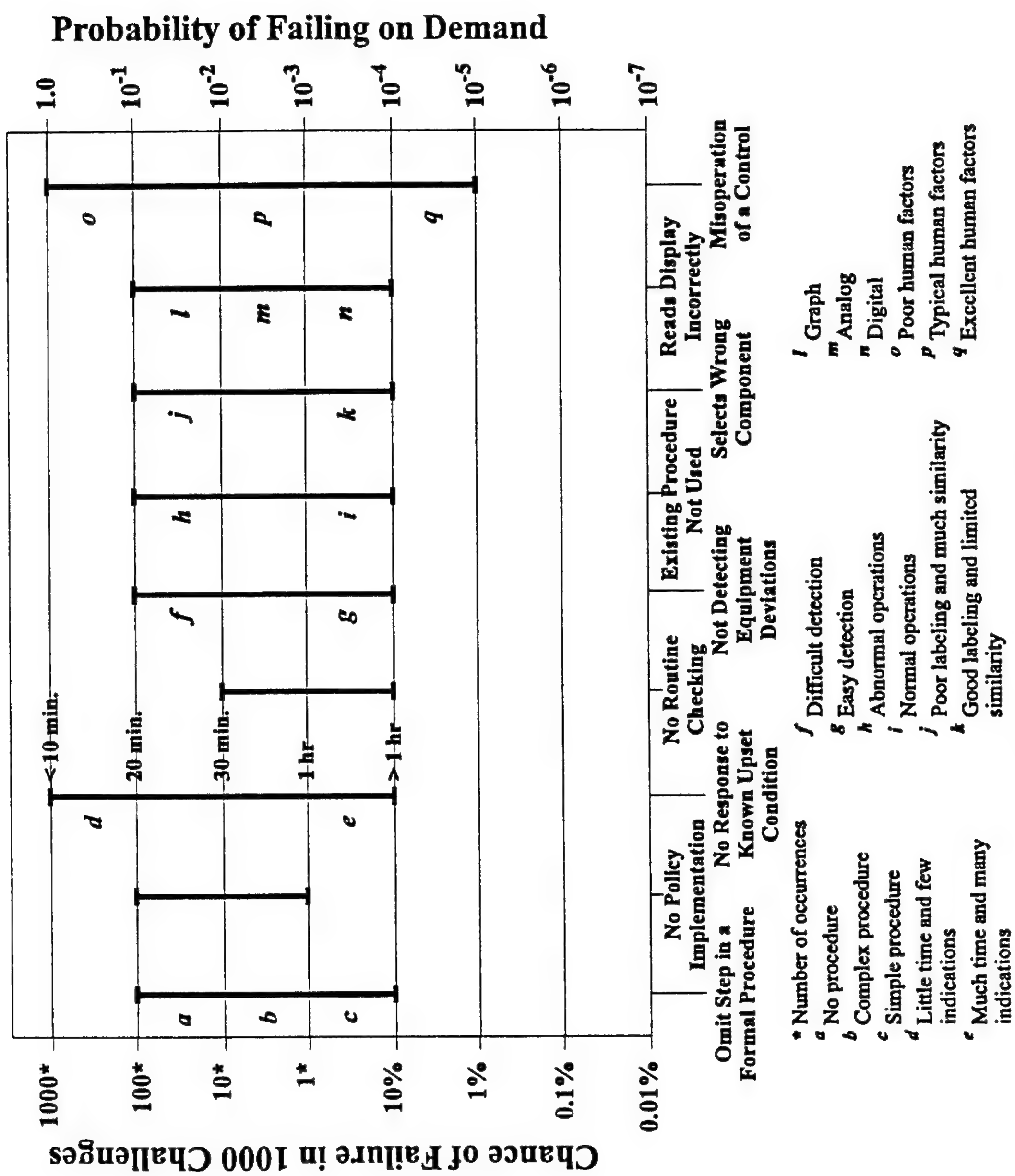


Common Events Involving Equipment Failing to Operate on Demand

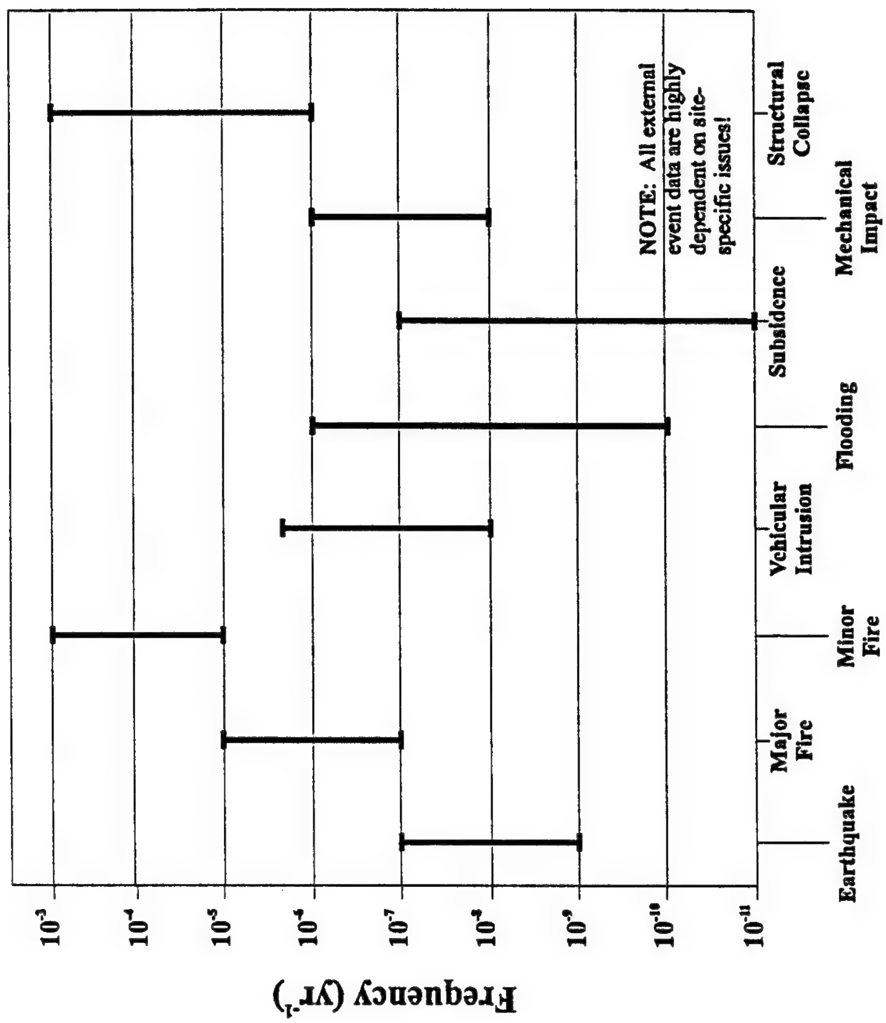


[a] Spurious operation
[b] Incorrect reading
[c] Control deviation
[d] Inadvertent trip

Common Events Involving Equipment Failures of Active Components



Common Human Error Probabilities



Common External Event Frequencies

Observations — Risk Characterization Using Categorization

- Less precise than quantitative characteristics
- Accuracy is dependent on several factors
- Generally very efficient to apply
- Often an excellent screening approach
- Results are often very subjective
- Can provide most types of risk-based information

Observations About Risk Characterization Using Categorization

- Less precise than quantitative characteristics
- Accuracy depends on
  - accuracy of scenario models
  - judgment/experience of those assigning scores for scenarios
  - quality of available scenario data
- Very efficient to apply, but some perspective about quantitative likelihood/consequences is necessary
- Often an excellent screening approach
- Results are often very subjective, especially for rare scenarios
- Can provide most types of risk-based information

While the risk categorization method is less precise than the point estimate method, it provides an excellent way to identify higher risk activities/operations. This method is also less resource intensive and much more efficient when many mishap scenarios must be evaluated. The difficulty encountered in using this approach is the subjective nature in assigning categories. Analysts often find it is hard to pick an appropriate frequency category for a very rare mishap scenario or an appropriate consequence category when a mishap scenario has a wide range of outcomes.

Another limitation of this method is in estimating total risk for a mishap. Mishap risk is estimated by summing the risk for all the contributing mishap scenarios. However, how do you add risk categories?

Qualitative Risk Characterization

- Subjective prioritization
- Basic scenario ranking
- Criteria-based scenario ranking

Qualitative Risk Characterization

As you would expect, qualitative methods are easier and faster to use in characterizing risk than quantitative methods. And these methods generally require less experience and expertise among analysis team members to use in characterizing scenario risk.

Subjective prioritization — an analysis team assigns mishap scenario risk (i.e., priority) based on its collective judgment of the likelihood and severity of the failures involved in the scenario

Basic scenario ranking — an analysis team assigns points to each failure in a mishap scenario based on the type of each failure. The points are summed to get the scenario risk. Higher scores indicate lower risks because more failures and/or failures of more reliable safeguards are required to complete the sequence

Criteria-based scenario ranking — an analysis team determines if mishap scenario risk is acceptable or unacceptable based on the number and type of failures described in the mishap scenario. Scenarios with unacceptable risks are subject to further control measures.

Subjective Prioritization

- Identify potential mishap scenarios using structured hazard analysis techniques
- Subjectively bin scenarios according to their perceived level of risk

Subjective Prioritization

Identify potential mishap scenarios using structured hazard analysis techniques (e.g., HAZOP, FMEA, and CCFA, described in Section 3)

Subjectively assign each scenario to a priority category based on the perceived level of risk. Priority categories can be

- low, medium, high
- numerical assignments
- priority levels

Application to 20 scenarios

- Priority 1 ➡ Scenarios 3, 7, 15
- Priority 2 ➡ Scenarios 1,5,16, 18, 19
- Priority 3 ➡ Scenarios 2, 4, 6, 8, 9, 10, 11, 12, 13, 14, 17, 20

As you can see from the simple example, this risk characterization process is very easy to use and highly dependent on the analyst's *perceptions* of risk. This method also provides limited direction to management on where to focus control efforts.

Observations about subjective prioritization

- Very subjective
- Provides only general prioritization of scenarios
- Very efficient to implement

Basic Scenario Ranking

- Identify potential mishap scenarios
- Score scenarios based on types/numbers of events
- Prioritize based on scores

Basic Scenario Ranking

- Identify potential mishap scenarios using structured hazard analysis techniques
- Score scenarios based on types/numbers of events in each scenario
  - human errors
  - active equipment failures
  - passive equipment failures
- Use scenario scores to prioritize scenarios

Example scoring guidelines

- 1 point for any event (operating conditions, environmental conditions, human actions, equipment actions, etc.) expected to occur regularly (EE)
- 2 points for each human error (HE)
- 3 points for each active equipment failure (AEF)
- 4 points for each infrequent external event (IEE)
- 5 points for each passive equipment failure (PEF)

The table on the next page presents a set of accident scenarios that were evaluated using a scenario ranking methodology. Note that in this example, the scenario that is ranked highest doesn't have the lowest score. This is because of the strong dependencies among the human errors associated with the highest ranked scenario. Common-cause failures can be difficult to explicitly factor into qualitative risk-based schemes.

Some ranked accident scenarios for catastrophic rupture of vessel "A"

Rank	Accident Scenario	Types of Events	Score Based on Types and Numbers of Events
1*	Operator leaves Valve "A" open, operator leaves Valve "B" open, and operator fails to verify that Valves "A" and "B" are closed before introducing hazardous material into the process	HE, HE, HE	6
2	Major earthquake	IEE	4
3	Mechanic improperly calibrates the relief valve on Vessel "A," and pressure control valve for Vessel "A" sticks closed	HE, AEF	5
4	Catastrophic rupture of Vessel "A"	PEF	5
5	Operator fails to open the isolation valve under the relief valve on Vessel "A" (after maintenance of the relief valve), operator fails to detect improperly positioned valve during monthly status checks of special valves, Operator inadvertently misdirects a high-pressure feed stream into Vessel "A," and operator fails to detect/ mitigate rising pressure (based on other pressure indications)	HE, HE, HE, HE	8
6	Operator fails to open the isolation valve under the relief valve on Vessel "A" (after maintenance of the relief valve), operator fails to detect improperly positioned valve during monthly status checks of special valves, pressure controller erroneously commands pressure control for Vessel "A" to close, and operator fails to detect/mitigate rising pressure (based on other pressure indications)	HE, HE, AEF, HE	9

*This scenario is ranked as more important than three other scenarios with lower scores because the analyst identified strong dependencies among the three human errors associated with this scenario.

Observations

- Less subjective than judgment-based approaches
- Provides only general prioritization of scenarios
- Basis of scoring has inherent limitations/inaccuracies
- Efficient to implement
- Good screening tool

The basic scenario ranking method avoids much of the subjectivity contained in the previous method. After scores are assigned to each failure in a mishap scenario, the values are totaled to yield a scenario risk score. Similarly, the risk scores for all scenarios that have the same outcome can be totaled to estimate a mishap risk. Thus, this method allows analysts to screen various types of mishaps as well as scenarios that contribute to mishaps.

Criteria-based Scenario Evaluation

- Establish criteria for accepting risks
- Identify potential mishap scenarios
- Compare scenarios to criteria
- Generate recommendations

Criteria-based Scenario Evaluation

- Establish pass/fail criteria for accepting risks based on the types and numbers of events in scenarios
- Identify potential mishap scenarios using structured hazard analysis techniques
- Compare identified scenarios to criteria
- Generate recommendations to address scenarios that do not meet acceptance criteria

Example criteria

The following table provides examples of pass/fail criteria that can be used in a criteria-based assessment scheme.

Type of Criteria	Examples
Number of safeguards that must fail before a specific consequence of interest occurs (i.e., the number of events in each scenario)	There may not be any one-event scenarios capable of causing a major explosion on a platform Two safeguards must be in place to prevent a release of H_2S from entering the platform's living quarters
Types of safeguards that must fail before a specific consequence of interest occurs (i.e., the types of events in each scenario)	There may not be a situation in which a high pressure excursion in a pipeline could occur without at least one equipment failure in addition to the equipment failure/ human error that initiated the high pressure (i.e., no complete dependence on human response to the upset condition) An active and a passive (or two passive) equipment protection are required for any scenario capable of causing a catastrophic consequence
Combinations of the number and types of safeguards that must fail before a specific consequence of interest occurs (i.e., the numbers and types of events in each scenario)	Single-event scenarios are only acceptable if the event is a passive equipment failure and the worst-case effect would not be catastrophic Scenarios involving multiple passive equipment failures are considered practically impossible unless there is some dependency (i.e., common cause) between the failures

Example of scenario evaluation

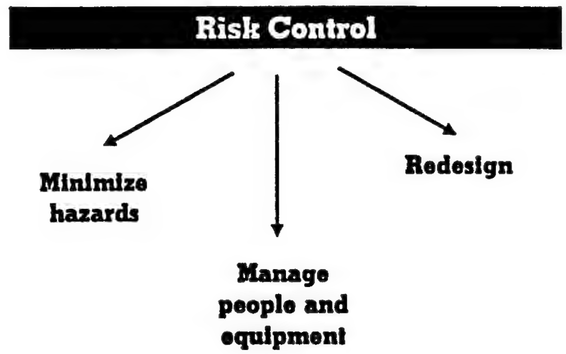
This table presents some mishap scenarios evaluated against preestablished criteria. Recommendations are made when the evaluation criteria are not met.

Item	Mishap Scenario	Types of Events	Acceptable?	Recommendation
1	Operator leaves Valve "A" open, operator leaves Valve "B" open, and operator fails to verify that Valves "A" and "B" are closed before introducing hazardous material into the process	HE, HE, HE	No	Needs equipment protection
2	Major earthquake	IEE	Yes	None
3	Mechanic improperly calibrates the relief valve on Vessel "A," and pressure control valve for Vessel "A" sticks closed	HE, AEF	Yes	None
4	Catastrophic rupture of Vessel "A"	PEF	Yes	None
5	Operator fails to open the isolation valve under the relief valve on Vessel "A" (after maintenance of the relief valve), operator fails to detect improperly positioned valve during monthly status checks of special valves, operator inadvertently misdirects a high-pressure feed stream into Vessel "A," and operator fails to detect/mitigate rising pressure (based on other pressure indications)	HE, HE, HE, HE	No	Needs equipment protection
6	Operator fails to open the isolation valve under the relief valve on Vessel "A" (after maintenance of the relief valve), operator fails to detect improperly positioned valve during monthly status checks of special valves, pressure controller erroneously commands pressure control for Vessel "A" to close, and operator fails to detect/mitigate rising pressure (based on other pressure indications)	HE, HE, AEF, HE	Yes	None

Observations

- Determine criteria and risk judgments
- Basis of criteria has inherent limitations/inaccuracies
- Efficient to implement
- Good screening tool

As you can see, the criteria-based ranking is a derivative of the basic scenario ranking method. The two key differences are that numerical scores are not used and the scenario risk results are binary (i.e., pass or fail). Specific recommendations are made based on deviations from the acceptance criteria. The criteria for establishing acceptability of scenario risk may be subjectively determined by the risk analyst or may be arrived at using the numerical scoring described in the scenario ranking method.



Risk goals and risk assessment results provide information on where the most significant risks exist. The final step in the risk management process is the application of controls to ensure that all risks are at an acceptable level. Management can control risks by:

Minimizing hazards — Hazards are inherent characteristics of a process or operation that present a threat to worker safety, the environment, or operation viability when failures or errors occur. By minimizing or eliminating the hazard, the risk associated with the hazard is minimized or eliminated.

For example, an ammonia refrigeration system has a toxic hazard associated with it. If a cooling coil leaks, worker safety is threatened. Switching the coolant to freon greatly reduces the safety hazard, but increases the environmental hazard. Switching to chilled water may eliminate the hazard.

Management — The control of risk is also achieved through the proper management of people and equipment. Personnel training; operating procedures; safe work practices; inspection; test, and maintenance procedures; quality assurance and quality control; and personal protective equipment requirements are just some of the management systems we use to control risk. Enhancing the effectiveness of existing systems or adding new ones may further reduce risk.

Redesign — The addition of new equipment or reconfiguration of existing equipment is another option we can use to control risk. For example, if the risk of an ammonia release from the refrigeration system is too high, we may add ammonia gas detectors and alarms to threatened work areas to help protect workers. Or we may identify external valve packing leakage as the major cause of ammonia releases and redesign the valves to have no packing (e.g., diaphragm valves).

United States Coast Guard
IRA Manual

Section 3
Overview of Common Hazard/ Risk Analysis Methodologies

Hazard/Risk Analysis

- Numerous hazard/risk analysis tools exist; however, the following features are common to most such tools:
  - structured
  - predictive
  - experience based
  - adaptive

Structured

Each hazard/risk analysis tool has some underlying structure intended to facilitate a thorough examination of potential problems for which the tool is being applied. Some tools have very rigid structures, while others are more flexible. Typically, more highly structured tools provide a more complete evaluation, but often require much more analysis effort than less structured tools. Although less structured analysis tools generally demand less skill to apply, they require more input from subject matter experts to compensate for issues that the basic nature of the analysis process might overlook.

Predictive

Although some hazard/risk analysis tools can be valuable for investigating mishaps that do occur, the principal use of such tools is to characterize the potential for future mishaps. Thus, hazard/risk analysis is generally a prediction about what is expected in the future. As with any forecast of the future, a mishap prediction has significant uncertainty and can be represented only as a "degree of belief." The certainty (or uncertainty) associated with mishap predictions creates a constant tension between:

1. the cost of providing greater certainty and
2. the value of more certain estimates to decision makers.

Experience Based

Hazard/risk analyses are predictive in nature, but do not ignore the past. Some of the best information about possible future mishaps is based on information about the types, frequencies, and severities of past mishaps in the same or other related operations/applications. Hazard/risk analyses use this information (as well as information about corrective actions that have already been implemented to address past mishaps) to develop perspective about expected future performance. Hazard/risk analysis tools incorporate this type of information from many sources, including objective records (equipment files, maintenance records, electronic databases, manufacturer information, etc.) and subjective opinions of subject matter experts (experienced engineers, operators, and technicians as well as vendor representatives and others).

Adaptive

Most hazard/risk analysis tools can be applied at various levels of detail (i.e., can be applied at very high or low levels of resolution) and to many types of systems/processes. This adaptive nature makes most hazard/risk analysis tools very flexible.

Information Available from Hazard/Risk Analysis

- Qualitative mishap descriptions
- Qualitative judgments about expected mishaps
- Quantitative measures of loss prevention-related "factors of merit"
- Relative importance of mishap contributors
- Recommendations for improvement

The format of outputs from various hazard/risk analysis tools are quite distinct, but can be divided into the following categories:

Qualitative mishap descriptions. Descriptions of sequences of events (equipment failures, human errors, and external influences) capable of producing mishaps of interest.

Qualitative judgments about expected mishaps. Subjective judgments (i.e., informed opinions) about whether the threat of possible mishaps is significant enough to prevent achievement of loss prevention goals/objectives. Frequently based on the numbers of events (single failures/errors versus multiple event scenarios) and types of events (active equipment failures, passive equipment failures, errors of omission, errors of commission, etc.) leading to mishaps. Often evaluated in relation to established benchmarks for which acceptance/rejection decisions have already been made (e.g., this scenario is less likely than another scenario for which no improvements were suggested).

Quantitative measures of loss prevention-related "factors of merit." Quantitative estimates of loss prevention-related parameters such as reliability, availability, environmental risk, personnel/public risk, economic risk, etc. Used to judge whether the threat of possible mishaps is significant enough to prevent achievement of numerical loss prevention goals/objectives (e.g., the system is expected to be available 97% of the time, which exceeds the goal of 95% availability). Sometimes includes evaluations ("what-if" scenarios) of sensitivity to changes such as implementation of recommendations, changes in operating conditions/strategies, etc.

Relative importance of mishap contributors. Identification of the most significant potential mishaps based upon the likelihood and/or consequences of those mishaps. Prioritizations by scenarios and/or specific failures/errors.

Recommendations for improvement. Suggestions for improving loss prevention performance. Include suggestions for new/improved engineered systems, administrative/management controls, and items for further evaluation. These recommendations may decrease the likelihood of a mishap and/or the consequences of a mishap.

A Life Cycle Approach to Performing Hazard/Risk Analysis

- Research
- Design
  - conceptual
  - preliminary
  - detailed
- Fabrication/ construction/ manufacturing
- Operation
  - startup
  - ongoing
- Decommissioning

Research

Analysis focus on assessing inherent safety and reliability of certain technologies. Primarily interested in technical models ("physics of failure") of how failures occur over time, number of demands, number of cycles, etc. Also interested in key parameters that must be controlled in design, manufacturing, and operation to translate research technology into viable applications.

Design

Analysis focus on ensuring that the selected configuration/operating strategy will provide the necessary loss prevention performance to meet overall performance goals/objectives. Keenly interested in identifying "weak links" and opportunities for improvements in components and systems.

Conceptual phase

Analysis focus on determining how overall performance goals/ objectives translate into goals/objectives for individual systems. Assessment (at a high level) of whether required loss prevention performance is realistically achievable and what modifications/ improvements would be necessary to meet overall goals/objectives. Comparison of various design concepts to determine which option(s) deserves further development based on a variety of factors, including project risk and expected life cycle costs (such as the cost of mishaps and their prevention).

Preliminary phase

Analysis focus on determining how individual system goals/objectives translate into component goals/objectives. Assessment (at a more detailed level) of whether required loss prevention performance is realistically achievable and what modifications/improvements would be necessary to meet system goals/objectives. Optimization of expected system performance characteristics based on a number of factors (including costs, loss of mission, risk, etc.).

Detailed phase

Analysis focus on ensuring that component selection and configuration allows systems to meet individual component goals/objectives. Assessment (at a component level) of whether required loss prevention performance is realistically achievable and what modifications/improvements would be necessary to meet component goals/objectives. Optimization of component selection based on a number of factors (including costs, loss of mission, risk, etc.). Also interested in:

1. critical parameters for safe and reliable fabrication/construction/manufacturing,
2. important operating limits and startup criteria,
3. appropriate preventive/predictive maintenance tasks, and
4. necessary spare parts/materials stores.

Fabrication/Construction/Manufacturing

Analysis focus on ensuring that established specifications have been satisfied and identifying any special fabrication/construction/manufacturing issues not identified during design that could affect loss prevention performance. Assessment of the potential significance of any identified field nonconformances as well as any proposed changes during fabrication/construction/manufacturing.

Operation

Analysis focus on optimization of operating/maintenance/supply strategies while achieving loss prevention goals/objectives.

Startup

Analysis focus on ensuring that operating/maintenance strategies (including plans, procedures, and training) promote realization of inherent safety and reliability and are optimized based on a variety of factors (including costs, loss of mission, risk, etc.).

Ongoing

Analysis focus on ensuring that:

1. changes (planned, unplanned, and unintentional) do not significantly affect loss prevention performance and
2. operating/maintenance strategies remain optimized based on a variety of factors (including costs, loss of mission, risk, etc.), especially in light of data that will become available over years of operation.

Decommissioning

Analysis focus on liability issues associated with decommissioning (e.g., safety, health, and environmental risks) and what actions to take to control those risks to acceptable levels.

Overview of Common Analysis Tools

- Hazard screening analysis tools
- Broadly applicable, detailed analysis tools
- Narrowly focused, detailed analysis tools

Screening Analysis Tools

Used for high-level analyses intended to:

1. provide a general characterization of expected mishaps and
2. identify the most significant areas of interest for further evaluation.

Often generate some effective recommendations for improvement, but seldom at a detailed level.

Example tools:

- Parts count analysis
- Pareto analysis
- Facility risk review (FRR)
- Safety review
- Relative ranking

Broadly Applicable, Detailed Analysis Tools

Used for more detailed analysis of complete systems that have been determined to be potentially important in some regard.

Example tools:

- Checklist analysis
- What-if analysis
- Hazard and operability analysis (HAZOP)
- Failure modes and effects analysis (FMEA)
- Fault tree analysis (FTA)
- Event tree analysis (ETA)
- Cause-consequence analysis (CCA)
- Markov analysis
- Block diagram analysis
- Systems approach to human element risk analysis

Narrowly Focused, Detailed Analysis Tools

Used for detailed analysis of specific items/issues/mechanisms that have been determined to be potentially important in some regard.

Example tools

- Weibull analysis
- Human reliability analysis (HRA)
- Common cause failure analysis (CCFA)
- Sneak circuit analysis (SCA)
- Software failure analysis
- Physics-of-failure modeling
- Worker and instruction evaluation (WISE)

Hazard Screening Analysis Tools

- Parts count analysis
- Pareto analysis
- Facility risk review (FRR)
- Safety review
- Relative ranking

Parts Count Analysis

Failure rate of component 1 (λ_1)
+ Failure rate of component 2 (λ_2)
+ Failure rate of component 3 (λ_3)
+ Failure rate of component 4 (λ_4)

•
•
•

= System Failure Rate (Λ)

$$\Lambda = \sum_{i=1}^{N} \lambda_i$$

Where N is the total number of components

Summary of Parts Count Analysis

Simple analysis method that sums the failure rates of individual components within a system capable of producing mishaps of interest to estimate the mishap's frequencies.

Brief summary of characteristics

- Systematic, structured assessment relying on simple summation of component data to generate meaningful estimates of system failure frequencies/likelihoods
- Primarily performed by an individual analyst working with available component data and generic component failure data sources
- Quality of the evaluation depends on the quality of the system documentation, the quality of component data, and the training of the analyst

Most common uses

Generally applicable for almost every type of analysis application, but most effectively used for systems whose risk characteristics are dominated by single event failures.

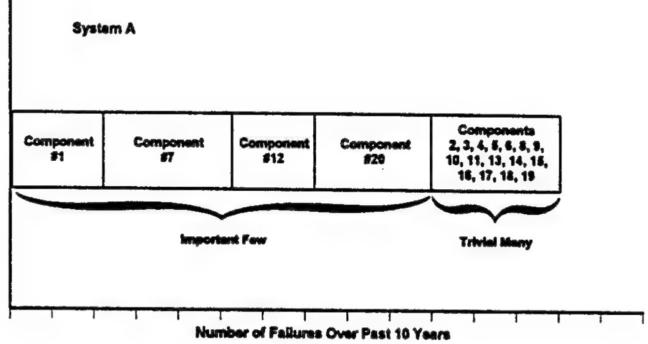
Often used as a rough screening approach for estimating reliability characteristics of systems, but can be effectively used to develop system failure rate predictions in relatively simple electronic and/or mechanical systems in which the system fails if any one part of the system fails.

Example from the Reliability Analysis Center's *Reliability Toolkit*

Unit	Qty	Failure Rate (FPMH)*	Data Source	Data Source Environment	Environment Adjustment Factor	Total Failure Rate (FPMH)
3½" Disk Drives	2	40	Field	Office	1	80
CD-ROM Drive	3	10	Handbook	Office	1	30
Hard Drive	1	35	Vendor test	Office	1	35
CPU Board	1	35	Field	Aircraft	.25	1
Keyboard	1	10	Field	Office	1	10
Monitor	1	40	Field	Aircraft	.25	10
Modem	1	3	Handbook	Office	1	3
					Totals (FPMH)	169
					Mean time between failures (hours)	5,917

*FPMH — Failures per million hours

Pareto Analysis



Summary of Pareto Analysis

Prioritization technique that identifies the most significant items among many. Employs the "80-20" rule, which states that 20% of the causes produce 80% of the effects.

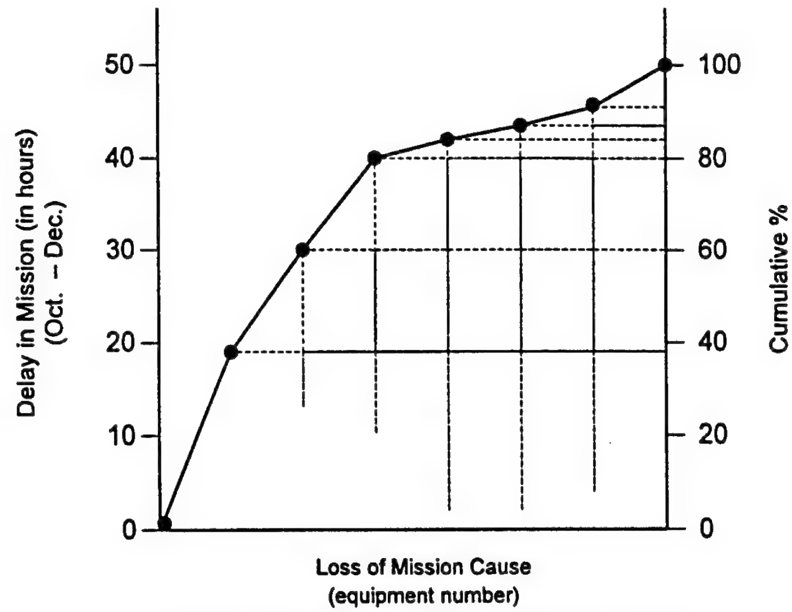
Brief summary of characteristics

- Used as both a system-level and component-level analysis technique
- Yields broad quantitative results that are graphically depicted on simple bar charts
- Depending on the information analyzed, the technique generally requires some form of data tracking (e.g., monitoring the number of mission losses or delays [recorded in hours])
- Applicable to any operating system

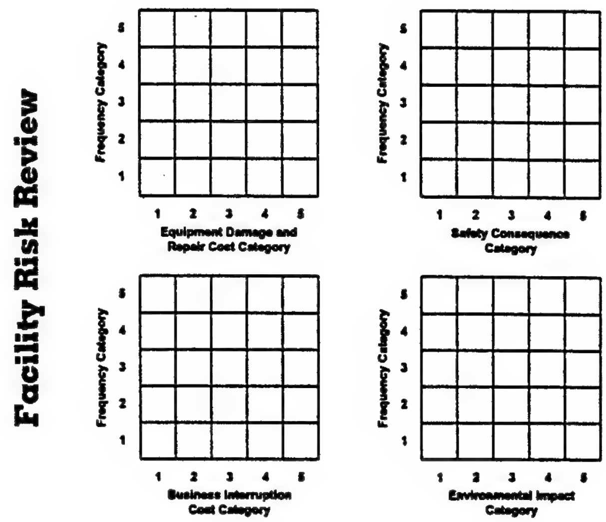
Most common uses

Most often used to rank system failure causes. Can be used to rank the causes that contribute to individual component failures. Also used to evaluate the reliability improvement resulting from system modifications using before-and-after data.

Example Pareto graph



Pareto Graph of Loss of Mission Contributors



Summary of Facility Risk Review (FRR)

Uses systematic analyses at a high level to provide a broad characterization of potential mishaps and to (1) generate recommendations for improvements and (2) focus further, more detailed analysis on the most important areas.

Brief summary of characteristics

- Systematic process built on the same structure as used for more detailed failure modes and effects analyses or event tree analyses, but applied only at system/subsystem levels (not down to the component level)
- Generally applied to entire facilities
- Applicable to virtually any system, but typically used for manufacturing processes
- Generates:
  1. qualitative descriptions of scenarios leading to potential problems
  2. rough estimates of equipment damage, repair cost, business interruption cost, safety risks, environmental risks, etc.
  3. recommendations for improvements and/or more detailed analysis

Most common uses

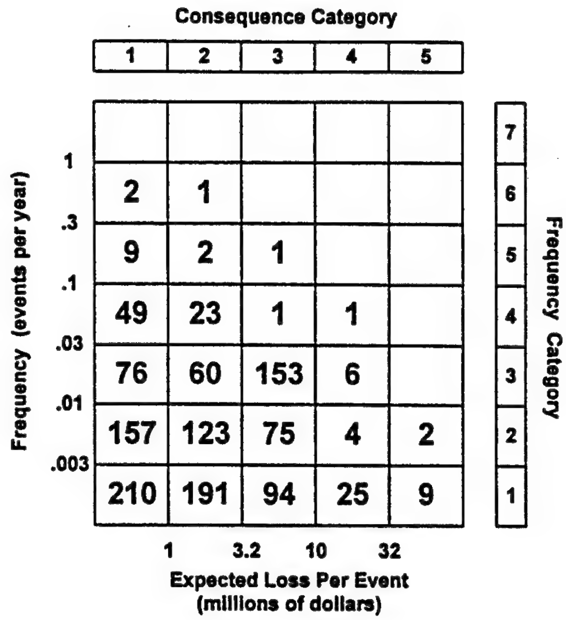
Primarily used to provide an effective screening of risks for entire facilities.

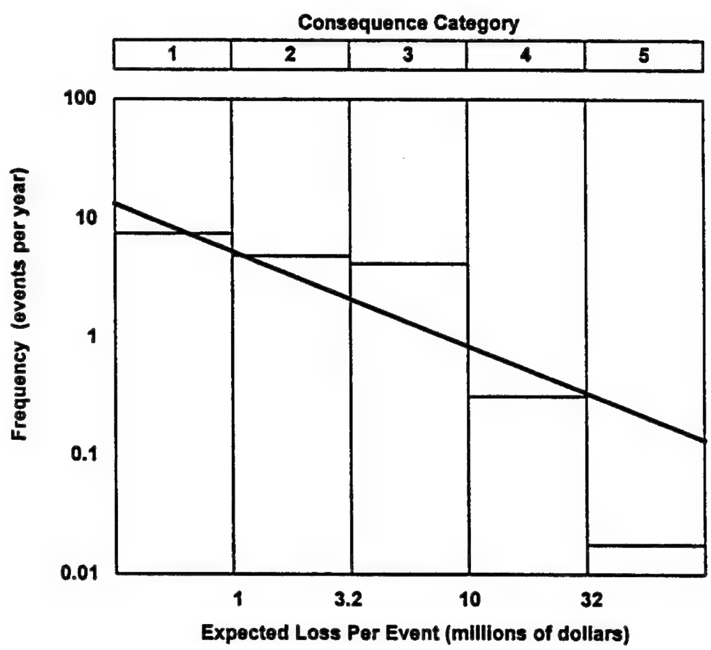
Example accident frequency categories

Category	Average Time Between Occurrences (years)	Frequency (per year)	Description
1	>300	<.003	Not expected to occur
2	100 – 300	.003 – .01	Not likely to occur during the lifetime of a facility, vessel, etc.
3	30 – 100	.01 – .03	Expected to occur no more than once during the lifetime of a facility, vessel, etc.
4	10 – 30	.03 – .1	Expected to occur no more than once or twice during the lifetime of a facility, vessel, etc.
5	3 – 10	.1 – .3	Expected to occur several times during the lifetime of a facility, vessel, etc.
6	1 – 3	.3 – 1.0	Expected to occur between once a year and once every 3 years
7	<1	>1.0	Expected to occur more than once a year

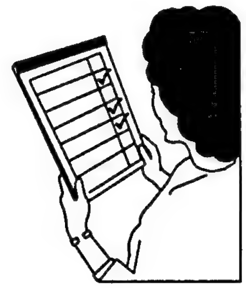
Example cost categories

Category	Frequency (per year)
1	Less than 1
2	1 to 3
3	3 to 10
4	10 to 30
5	More than 30


Consequence Category
1 2 3 4 5
Frequency (events per year)
1
.3
.1
.03
.01
.003
2 1
9 2 1
49 23 1 1
76 60 153 6
157 123 75 4 2
210 191 94 25 9
7 6 5 4 3 2 1
Frequency Category
1 3.2 10 32
Expected Loss Per Event
(millions of dollars)


Consequence Category
1 2 3 4 5
100
10
1
0.1
0.01
Frequency (events per year)
1 3.2 10 32
Expected Loss Per Event (millions of dollars)

Safety Review



Summary of Safety Review

Detailed system evaluation/inspection to identify hazardous conditions and practices based on general guidelines (including regulatory requirements and company standards).

Brief summary of characteristics

- Assessments range from very informal to very formal
- Typically performed by an individual or small group of safety experts, although larger groups are sometimes used
- Generally includes interviews with subject matter experts, reviews of procedures, and visual inspection of equipment conditions and operations
- Generates qualitative summaries of areas for improvement and areas where current conditions/practices seem appropriate
- Quality of evaluation determined by experience of reviewers

Most common uses

Generally used in conjunction with checklist analyses (as described later). Also, frequently used as an inspection tool to ensure that required safeguards are in place. Safety reviews are used as the basis for most unstructured system design reviews and field safety reviews. These reviews are also often used for pre-startup safety review of systems and safety reviews of special/unique operations.

Relative Ranking

$$\text{Loss Prevention Performance} \propto \text{Hazard / Risk Index} = F_n(\text{Factor}_1, \text{Factor}_2, \ldots)$$

Some example hazard/risk index factors:

- robust design margins
- levels of redundancy
- human factors considerations
- vulnerability to external events
- use of proven technology
- etc.

Summary of Relative Ranking

Uses attributes of a process or activity to calculate index numbers that are useful for making relative comparisons of various processes and activities (and in some cases can be correlated to absolute risk estimates).

Brief summary of characteristics

- Very systematic process built on the experience of the ranking system developers
- Generally performed by an individual (sometimes a small group) trained to understand the ranking system, not necessarily safety/reliability experts
- Based mostly on interviews, documentation reviews, and field inspections
- Used most often as a system-level analysis technique
- Applicable to almost any system or activity
- Generates:
  1. index numbers that provide ordered lists of processes or activities
  2. lists of attributes contributing most to risks
- May be used to characterize absolute risks associated with a process or activity
- Quality of evaluation primarily determined by the relevance/quality of the ranking system and the training of the user(s)

Most common uses

Primarily used to compare various situations/options with applications in facility siting and alternative design comparisons.

Can be used to prioritize processes or activities for further evaluation according to their rankings.

Example results

System	Factor Scores						Hazard/Risk Index Score
	Design Margin	Level of Redundancy	Human Factors	Vulnerability to External Event	Proven Technology	. . .	
Option 1	9	3	7	5	8		64
Option 2	7	6	6	5	5		58
Option 3	5	9	7	5	3		55

Broadly Applicable, Detailed Analysis Tools

- Checklist analysis
- What-if analysis
- Hazard and operability analysis (HAZOP)
- Failure modes and effects analysis (FMEA)
- Fault tree analysis (FTA)
- Event tree analysis (ETA)
- Cause-consequence analysis (CCA)
- Markov analysis
- Block diagram analysis
- Systems approach to human elements risk analysis

Checklist Analysis

Evaluation Points	Yes	No	Not Evaluated	Comments
Subject Area 1				
Evaluation Point 1-1	✓			
Evaluation Point 1-2	✓			
Evaluation Point 1-3		✓		Recommendation A
•				
•				
•				
Subject Area 2				
Evaluation Point 2-1			✓	
Evaluation Point 2-2	✓			
Evaluation Point 2-3	✓			
•				
•				
•				
Subject Area 3				
•				
•				
•				

Summary of Checklist Analysis

Systematic evaluation against preestablished criteria in the form of one or more checklists.

Brief summary of characteristics

- Very systematic approach built on the historical knowledge included in checklist questions
- Used for system-level or component-level analysis
- Applicable to any system or procedure
- Generally performed by an individual (sometimes a small group) trained to understand the checklist questions, not necessarily safety experts
- Based mostly on interviews, documentation reviews, and field inspections
- Generates qualitative lists of conformance and nonconformance determinations with recommendations for correcting nonconformances
- Quality of evaluation primarily determined by the experience of people creating the checklist(s) and the training of the checklist user(s)

Most common uses

Most often used as a supplement or integral part of another method (especially what-if analysis) to address specific requirements, but seldom used alone because of the possibility of overlooking unique circumstances/issues not covered in the checklist.

Example checklist

A. Piping and Valves

1. Is the piping specification suitable for the process conditions, considering:
   - compatibility with process materials and contaminants (e.g., corrosion and erosion resistance)?
   - compatibility with cleaning materials and methods (e.g., etching, steaming, pigging)?
   - normal pressure and temperature?
   - excess pressure (e.g., thermal expansion or vaporization of trapped liquids, blocked pump discharge, pressure regulator failure)?
   - high temperature (e.g., upstream cooler bypassed)?
   - low temperature (e.g., winter weather, cryogenic service)?
   - cyclical conditions (e.g., vibration, temperature, pressure)?
   - external corrosion because of the piping's design (e.g., material of construction, insulation on cold piping), location (e.g., submerged in a sump), or environment (e.g., saltwater spray)?
2. Is there any special consideration, for either normal or abnormal conditions, that could promote piping failure? For example:
   - Would flashing liquids autorefrigerate the piping below its design temperature?
   - Could accumulated water freeze in low points or in dead-end or intermittent service lines?
   - Could cryogenic liquid carry-over chill the piping below its design temperature?
   - Could heat tracing promote an exothermic reaction in the piping, cause solids to build up in the piping, or promote localized corrosion in the piping?
   - Could the pipe lining be collapsed by vacuum conditions?
   - Could a process upset cause corrosive material carry-over in the piping, or could dense corrosive materials (e.g., sulfuric acid) accumulate in valve seats, drain nipples, etc.?
   - In high temperature reducing service (e.g., hydrogen, methane, or carbon monoxide), could metal dusting cause catastrophic failure? Is the piping protected by suitable chemical addition (e.g., sulfides)?
   - Is the piping vulnerable to stress corrosion cracking (e.g., caustic in carbon steel piping, chlorides in stainless steel piping)? Should the piping be stress relieved?
   - Is the piping vulnerable to erosion? Are piping elbows and tees designed to minimize metal loss, and are they periodically inspected?
   - Could rapid valve closure or two-phase flow cause hydraulic hammer in the piping? Should valve opening/closing rates be dampened to avoid piping damage?
   - Are there flexible connections that could distort or crack?
3. Can piping sizes or lengths be reduced to minimize hazardous material inventories?
4. Have relief devices been installed in piping runs where thermal expansion of trapped fluids (e.g., chlorine) would separate flanges or damage gaskets?
5. Are piping systems provided with freeze protection, particularly cold water lines, instrument connections, and lines in dead-end service such as piping at standby pumps? Can the piping system be completely drained?
6. Were piping systems analyzed for stresses and movements resulting from thermal expansion and vibration? Are piping systems adequately supported and guided? Will any cast-iron valves be subjected to excessive stresses that could fracture them? Will pipe linings crack (particularly at the flange face) because of differential thermal expansion?

7. Are bellows, hoses, and other flexible piping connections really necessary? Could the piping system be redesigned to eliminate them? Are the necessary flexible connections strong enough for the service conditions?
8. What are the provisions for trapping and draining steam piping?
9. Which lines can plug? What are the hazards of plugged lines?
10. Are provisions made for flushing out all piping during startup and shutdown? Are hoses, spools, jumpers, etc., flushed or purged before use?
11. Are the contents of all lines identified?
12. Are there manifolds on any venting or draining systems and, if so, are there any hazards associated with the manifolds?
13. Are all process piping connections to utility systems adequately protected against potentially hazardous flows?
    - Are there check valves or other devices preventing backflow into the utility supply?
    - Are there disconnects (spools, hoses, swing elbows, etc.) with suitable blinds or plugs for temporary or infrequently used utility connections?
    - Are there double blocks and bleeds for permanent utility connections?
14. Are spray guards installed on pipe flanges in areas in which a spraying leak could injure operators or start fires?
15. Will the piping insulation trap leaking material and/or react exothermically with it?
16. Have plastic or plastic-lined piping systems been adequately grounded to avoid static buildup?
17. Are there remote shutoff devices on off-site pipelines that feed into the unit or storage tanks?
18. Can bypass valves (for control valves or other components) be quickly opened by operators?
    - What hazards may result if the bypass is opened (e.g., reverse flow, high or low level)?
    - What bypass valves are routinely opened to increase flow, and will properly sized control valves be installed?
    - Is the bypass piping arranged so it will not collect water and debris?
    - Is there a current log of open bypass valves kept in the control room so operators can ensure that they are reclosed if necessary in an emergency?
19. How are the positions of critical valves (block valves beneath relief devices, equipment isolation valves, dike drain valves, etc.) controlled (car seals, locks, periodic checks, etc.)?
20. How are the positions of critical valves (e.g., emergency isolation valves, dump valves) indicated to operators? Is the position of all nonrising stem valves readily apparent to the operators? Do control room displays directly indicate the valve position, or do they really indicate some other parameter, such as actuator position or torque, application of power to the actuator, or initiation of a control signal to the actuator?
21. Are block valves or double block and bleed valves required:
    - because of high process temperatures?
    - because of high process pressures?
    - because the process material is likely to erode or damage valve internals?
    - because the process material is likely to collect on the valve seat?
    - for worker protection during maintenance on operating systems?

22. Are critical isolation valve actuators powerful enough to close the valves under worst-case differential pressure conditions (including backflow) in the event of a rupture?
23. Are chain operators for valves adequately supported and sized to minimize the likelihood of valve stem breakage?
24. How will control valves react to loss of control medium or signal? Do the control valves:
    - reduce heat input (cut firing, reboiling, etc.)?
    - increase heat removal (increase reflux, quench, cooling water flow, etc.)?
    - reduce pressure (open vents, reduce speed of turbines, etc.)?
    - maintain or increase furnace tube flow?
    - ensure adequate flow at compressors or pumps?
    - reduce or stop input of reactants?
    - reduce or stop makeup to a recirculating system?
    - isolate the unit?
    - avoid overpressuring of upstream or downstream equipment (e.g., by maintaining level to avoid gas blowby)?
    - avoid overcooling (below minimum desired temperature)?
25. Will control valve malfunction result in exceeding the design limits of equipment or piping?
    - Are upstream vessels between a pressure source and the control valve designed for the maximum pressure when the control valve closes?
    - Some piping's class decreases after the control valve. Is this piping suitable if the control valve is open and the downstream block closed? Is other equipment in the same circuit?
    - Is there any equipment whose material selection makes it subject to rapid deterioration or failure if any specific misoperation or failure of the control valve occurs (overheating, overcooling, rapid corrosion, etc.)?
    - Will the reactor temperature run away?
    - Is the three-way valve used in a pressure-relieving path the equivalent of a fully open port in all valve positions?
26. Is there provision in the design for a single control valve to fail:
    - in the worst possible position (usually opposite the fail-safe position)?
    - with the bypass valve open?
27. Upon a plantwide or unitwide loss of control medium or signal, which valves should fail to a position that is different from their normal failure positions? How were the conflicts resolved?
28. Can the safety function of each automatically controlled valve be tested while the unit is operating? Will an alarm sound if the sensing-signal-control loop fails or is deactivated? Should any bypass valves be car sealed or locked closed?
29. Are battery limit block valves easily accessible in an emergency?
30. Are controllers and control valves readily accessible for maintenance?

Summary of What-if Analysis

Questions	Responses
■ "What if {a specific component} fails?" ■ "What if {a specific process upset} occurs?" ■ "What if {a specific human error} occurs?" ■ "What if {a specific external event} occurs?"	"{Immediate system condition} potentially leading to {consequence of interest} if {applicable safeguards} fail"

Summary of What-if Analysis

Brainstorming approach that uses broad, loosely structured questioning to (1) postulate potential system upsets that may result in mishaps and (2) ensure that appropriate safeguards against those mishaps are in place.

Brief summary of characteristics

- Systematic but loosely structured assessment relying on brainstorming to generate a comprehensive review and a team of system experts to ensure that appropriate safeguards against mishaps are in place
- Typically performed by one or more teams with diverse backgrounds and experience who participate in group review meetings of system documentation and field inspections
- Applicable to any system or procedure
- Used as a system-level or component-level analysis technique
- Generates qualitative descriptions of potential mishaps (in the form of questions and responses) as well as lists of recommendations for preventing problems
- Quality of the evaluation depends on the quality of the system documentation, the training of the review team leader, and the experience of the review team(s)

Most common uses

Generally applicable for almost every type of analysis application, especially those dominated by relatively simple failure scenarios.

Occasionally used alone, but most often used to supplement other, more structured techniques (especially checklist analysis).

Example what-if review summary

Summary of What-if Review

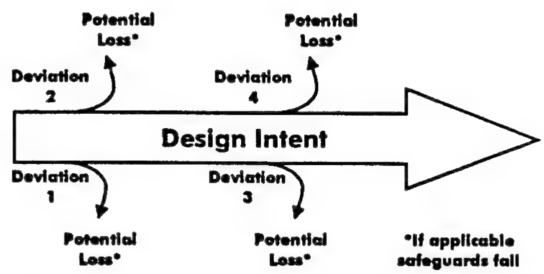
Date: 02/05/97 Page: 1

Process and Location: *VCM Plant Concept* Topic Investigated: *Safety Hazards*

Equipment/Task Intentions: *Direct Chlorination Reactor Feeds*

What if . . . ?	Consequence/Hazard	Recommendation	Responsible Individual	Initial and Date When Resolved
1. Ethylene feed is contaminated	1. Typical contaminant in ethylene is oil. Oil will react energetically with chlorine. However, the amount of oil in ethylene is usually small, and the large quantity of ethylene dichloride (EDC) in the reactor should quench any oil/chlorine reaction	1.a Verify that high purity ethylene is available and verify reliability of supply 1.b Determine the reaction kinetics for oil/chlorine reactions	1.a Ethylene expert 1.b Chemist	
2. Chlorine feed is contaminated	2. Typical contaminant in chlorine is water. Large quantities of water in chlorine would cause equipment damage in the chlorine plant and cause a shutdown well before it made it to the VCM plant. Small quantities of water should be no problem	2.a Verify that water content in ethylene supplies is very low	2.a Ethylene expert	

Hazard and Operability Analysis



Guide Word + Process Condition = Deviation

Summary of Hazard and Operability (HAZOP) Analysis

Inductive approach that uses a very systematic process (using special guide words) for postulating deviations from design intents for sections of systems and ensuring that appropriate safeguards are in place to help prevent mishaps.

Brief summary of characteristics

- Systematic, highly structured assessment relying on HAZOP guide words and team brainstorming to generate a comprehensive review and ensure that appropriate safeguards against mishaps are in place
- Typically performed by a multidisciplinary team
- Applicable to any system or procedure
- Used most as a system-level analysis technique
- Generates primarily qualitative results, although some basic quantification is possible

Most common uses

Primarily used for identifying safety hazards and operability problems of continuous process systems (especially fluid and thermal systems). Can also be used to review procedures and sequential operations.

Example results

HAZOP Deviation Guide

Process Variables / Guide Words	No, Not, None	Less, Low, Short	More, High, Long	Part of	As Well As, Also	Other Than	Reverse
Flow	No Flow	Low Rate, Low Total	High Rate, High Total	Missing Ingredient	Misdirection, Impurities	Wrong Material	Backflow
Pressure	Open to Atmosphere	Low Pressure	High Pressure	—	—	—	Vacuum
Temperature	Freezing	Low Temperature	High Temperature	—	—	—	Auto-refrigeration
Level	Empty	Low Level	High Level	Low Interface	High Interface	—	—
Agitation	No Mixing	Poor Mixing	Excessive Mixing	Mixing Interruption	Foaming	—	Phase Separation
Reaction	No Reaction	Slow Reaction	Runaway Reaction	Partial Reaction	Side Reaction	Wrong Reaction	Decomposition
Time, Procedure	Skipped or Missing Step	Too Short, Too Little	Too Long, Too Much	Action(s) Skipped	Extra Action(s) (Shortcuts)	Wrong Action	Out of Order, Opposite
Speed	Stopped	Too Slow	Too Fast	Out of Synch	—	Web or Belt Break	Backward
Special	Utility Failure	External Leak	External Rupture	Tube Leak	Tube Rupture	Startup, Shutdown, Maintenance	—

Other Variables: Concentration, Viscosity, pH, Static, Voltage, Current, etc.

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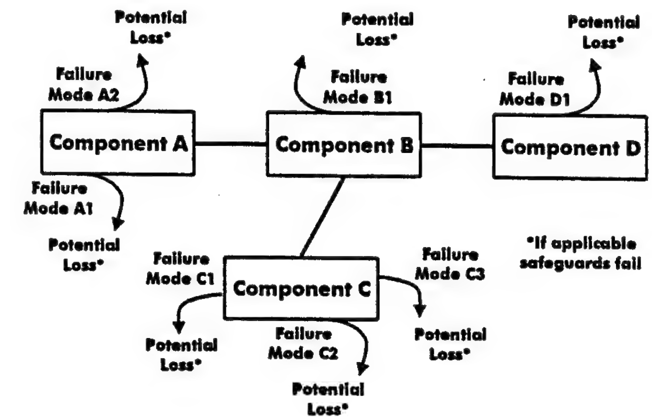
Example HAZOP table

Table B.5 HAZOP Review of XYZ Unit

Item Number	Deviation	Causes	Consequences	Safeguards	Recommendations
21.0 LINE – STRIPPER REFLUX LINE FROM STRIPPER ACCUMULATOR 16-12 TO STRIPPER 16-8, INCLUDING STRIPPER REFLUX PUMPS P-78 (dwg: m-62-3)					
21.1	High flow	Fails to close on command — LV-27 Spuriously commanded open — LV-27 Operator inadvertently opens or fails to close the manual isolation valve in the bypass around LV-27 Operator sets LV-27 at wrong setpoint	High level (in bottom of the tower) in the Stripper 16-8 (see 17.1) Low temperature in the Stripper 16-8 (see 17.6) Low level in the Stripper Reflux Accumulator 16-12 (see 19.2)	Local flow indicator (F I-40A) Flow indicator (FI-40)	
21.2	Low/no flow	Plugging — LV-27 Fails to open on command — LV-27 Spuriously commanded closed — LV-27 Operator sets LV-27 at wrong setpoint Loss of driver (motor) — P-7/8 Loss of 480V electrical power (for pumps) – utilities (see 26.4) Low level in the Stripper Reflux Accumulator 16-12 (see 19.2)	Low level (in draw tray for the reboiler) in the Stripper 16-8 (see 17.4) High temperature in the Stripper 16-8 (see 19.1) High level in the Stripper Reflux Accumulator 16-12 (see 19.1) Potential cavitation of pumps P-7/8, resulting in equipment damage and loss of containment (see 21.11) Unplanned shutdown of the unit, leading to a diversion of tail gas to the thermal oxidizer that results in an environmental permit exceedance	Suction screens at inlet of pumps P-7/8 Local flow indicator (FI-40A) Flow indicator (FI-40) Spare pump on standby (manual start) Local pressure indicator (PG-50, PG-51)	

Failure Modes and Effects Analysis



Summary of Failure Modes and Effects Analysis (FMEA)

Inductive approach that (1) considers how the failure modes of each system component could result in mishaps and (2) ensures that appropriate safeguards against such problems are in place. A quantitative version of FMEA is known as failure modes, effects, and criticality analysis (FMECA).

Brief summary of characteristics

- Systematic, highly structured assessment relying on evaluation of component failure modes and team experience to generate a comprehensive review and ensure that appropriate safeguards against mishaps are in place
- Used as a system-level and component-level analysis technique
- Applicable to any well-defined system
- Sometimes performed by an individual working with system experts through interviews and field inspections, but also can be performed by an interdisciplinary team with diverse backgrounds/experience participating in group review meetings of system documentation and field inspections
- Generates qualitative descriptions of potential mishaps (failure modes, root causes, effects, and safeguards) as well as lists of recommendations for reducing risks
- Can provide quantitative failure frequency and/or consequence estimates

Most common uses

Primarily used for reviews of mechanical and electrical systems.

Typical failure modes for some components

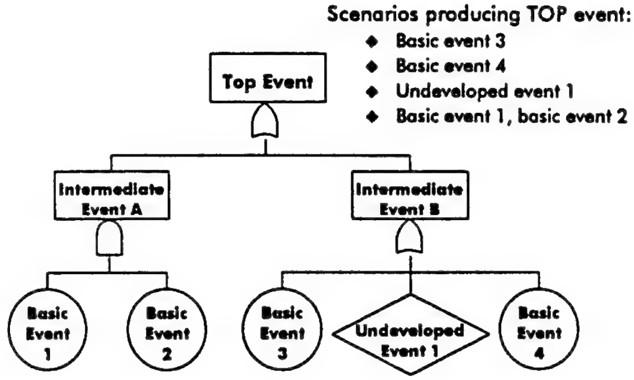
Component	Failure Mode
Pump	External leak External rupture Fails to start Fails off while running Starts prematurely Operates too long Operates at degraded head/flow performance (too fast, too slow, etc.)
Valves/dampers	External leak External rupture Internal leak Plugged Fails to open Fails to close Fails to change position Spurious positioning Opens prematurely Closes prematurely
Gauges/indicators/ recorders	Fails with no output signal Fails with a low output signal Fails with a high output signal Fails to respond to an input change Spurious output signal
Motor	Fails to start Fails off while running Starts prematurely Starts too late Operates too long Operates at degraded torque/rotational speed performance (runs backwards, too fast, too slow, etc.)

Example FMEA table

PERIPHERAL EQUIPMENT SUBSYSTEM FOR THE ROBOT

FAILURE MODE EVENT IDENTIFICATION			FAILURE MODE CAUSE & EFFECT ANALYSIS		FAILURE MODE FREQUENCY AND CONSEQUENCE QUANTIFICATION							FAILURE MODE EVALUATION	
Item	Component Description	Failure Mode	Failure Mode Causes	Failure Mode System Effects	Event Frequency (Event/YR)	Equipment Damage Cost ($/Event)	Business Interruption Cost ($/Event)	Repair Time Cost ($/Event)	Safety Category	Total Cost ($/Event)	Total Cost Risk ($/YR)	Failure Mode Safeguards and Comments	Recommended Action for Failure Mode
1.1	Electric power source	Fails to supply power to motors	Internal circuit failures due to overheating, corrosion, vibrations, or impacts Defective fuse	Loss of drive power to all motion axes Potential damage to the end effector, equipment, or parts in workspace, and damage or injury to other equipment or personnel in vicinity	4.836E-02	915.75	4,268.30	244.14	4	5,428.19	262.51	Insuring proper install/maint., high initial quality, and isolation from the environment are key operating parameters. These should be addressed in install/maint. and design Loss of motion may allow other interacting equipment to damage the robot	Recs. 1 and 2 for install/main. and design Rec. 15 for shutting down feed lines and interacting equipment during robot loss of power or error signal Rec. 16 for using an alternative power source to send loss of power signal Rec. 17 for requiring re-calibration of robot, with manual ignition, after error or loss of power equipment
1.2	Electric power supply unit	Fails to limit current to motors	Indirect or defective fuse Incorrect current set for operation	Damage to motors or motor drivers with loss of single or multiple axis motion Potential damage to the end effector, equipment or parts in workspace, and damage or injury to other equipment or personnel in vicinity	1,472E-03	774.65	3,899.54	212.53	3	4,886.72	7.19	Insuring proper install/maint. and initial quality are key operating parameters. These should be addressed in install/maint. and design	Recs. 1 and 2 for install/main. and design

Fault Tree Analysis



Summary of Fault Tree Analysis (FTA)

Deductive analysis that graphically models (using Boolean logic) how logical relationships between equipment failures, human errors, and external events can combine to cause mishaps.

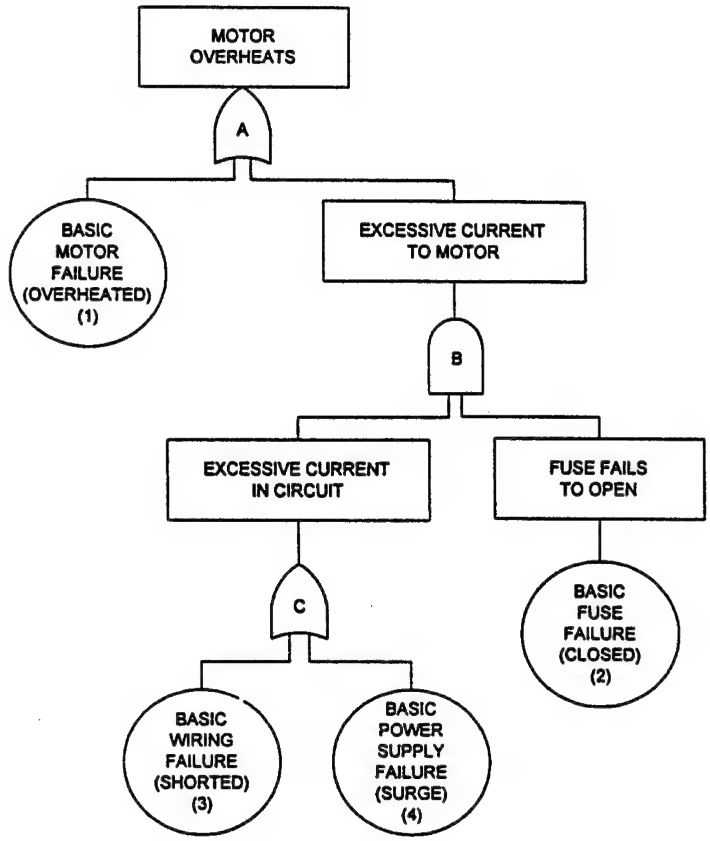
Brief summary of characteristics

- Systematic, highly structured assessment relying on the analyst's experience to generate a comprehensive review and ensure that appropriate safeguards against mishaps are in place
- Used most as a system-level analysis technique
- Consideration of human errors and common-cause failures strongly influences results
- Primarily performed by an individual working with system experts through interviews and field inspections
- Generates:
  1. qualitative descriptions of potential mishaps (combinations of events causing specific mishaps of interest)
  2. quantitative estimates of mishap frequencies and relative importances of various accident sequences/contributing events
  3. lists of recommendations for reducing risks
  4. quantitative evaluations of recommendation effectiveness
- Quality of the evaluation depends on the quality of the system documentation, the training of the analyst, and the experience of the subject matter experts assisting the analyst

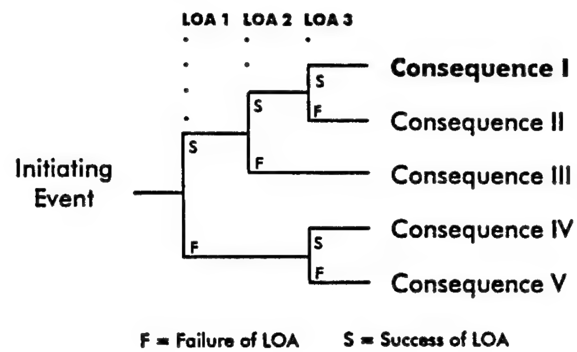
Most common uses

Generally applicable for almost every type of analysis application, but most effectively used to address the fundamental causes of specific mishaps dominated by relatively complex combinations of events.

Example fault tree



Event Tree Analysis



Summary of Event Tree Analysis (ETA)

Inductive analysis that graphically models (using decision trees) the possible outcomes from an initiating event capable of producing a mishap of interest.

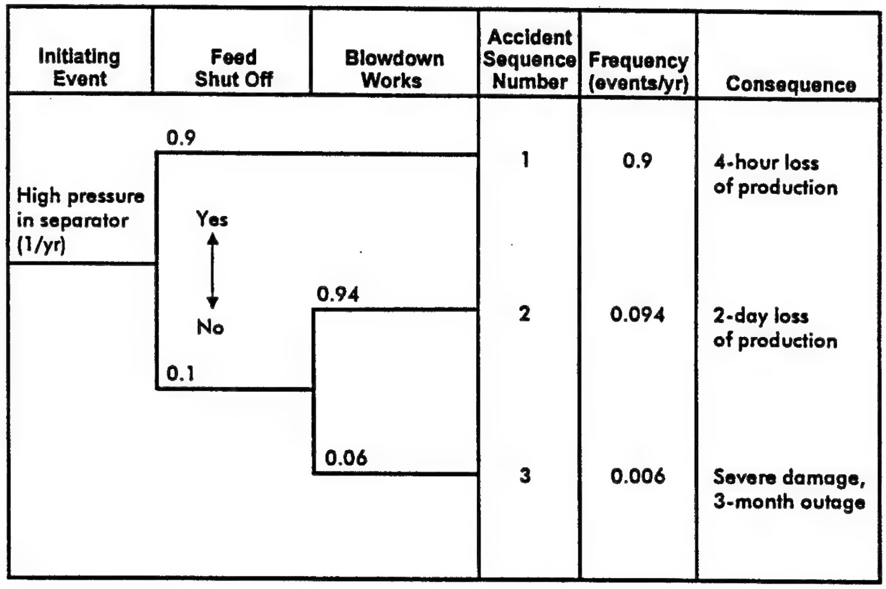
Brief summary of characteristics

- Systematic, highly structured assessment relying on the analyst's experience to generate a comprehensive review and ensure that appropriate safeguards against mishaps are in place
- Primarily performed by an individual working with system experts through interviews and field inspections
- Generates:
  1. qualitative descriptions of potential mishaps (combinations of events producing various types of mishaps from common initiating events)
  2. quantitative estimates of mishap frequencies/likelihoods and relative importances of various accident sequences/contributing events
  3. lists of recommendations for reducing risks
  4. quantitative evaluations of recommendation effectiveness
- Quality of the evaluation depends on the quality of the system documentation, the training of the analyst, and the experience of the subject matter experts assisting the analyst

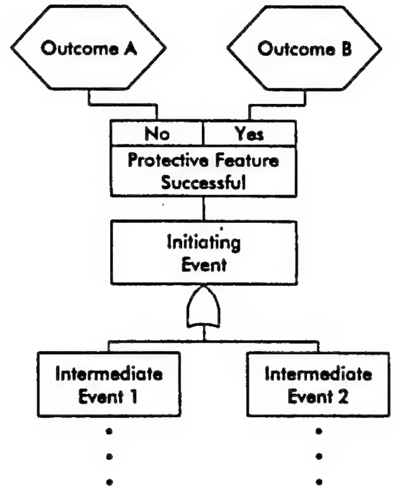
Most common uses

Generally applicable for almost every type of analysis application, but most effectively used to address possible outcomes of initiating events for which multiple safeguards (lines of assurance) are in place as protective features.

Example event tree



Cause-Consequence Analysis



Summary of Cause-Consequence Analysis (CCA)

Combination of fault tree analysis and event tree analysis using slightly different graphical symbols.

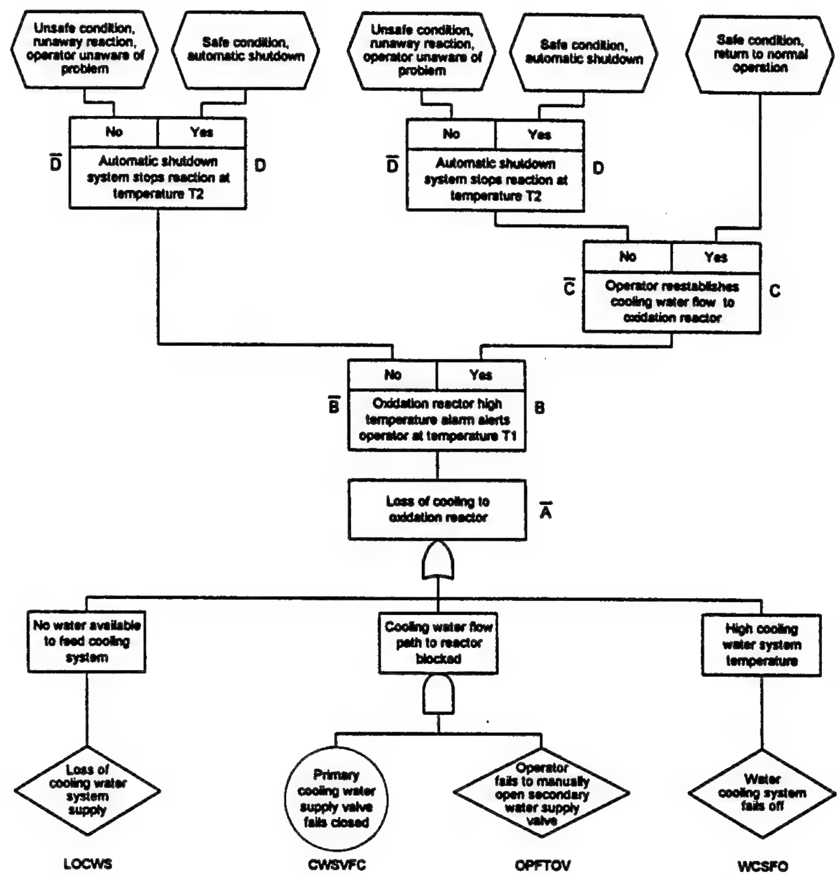
Brief summary of characteristics

See the descriptions for fault tree analysis and event tree analysis.

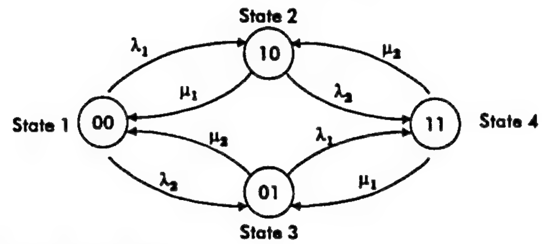
Most common uses

See the descriptions for fault tree analysis and event tree analysis.

Example cause-consequence tree



Markov Analysis



Two-component system:

- State 1: Both working, system working
- State 2: Component 1 failed, component 2 working, system working
- State 3: Component 1 working, component 2 failed, system working
- State 4: Both failed, system failed

Summary of Markov Analysis

Model of all possible states of a system (and transitions between states) that allows an analyst to calculate frequencies/probabilities of system states of interest (typically failure states that result in mishaps).

Brief summary of characteristics

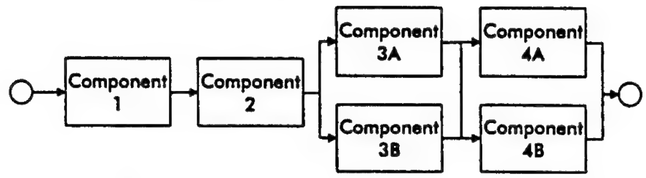
- Systematic, highly structured assessment relying on the analyst's experience to generate a comprehensive review and ensure that appropriate safeguards against mishaps are in place
- Primarily performed by an individual analyst working with system experts through interviews and field inspections
- Generates:
  1. qualitative descriptions of potential failure states producing mishaps (combinations of events causing specific mishaps of interest)
  2. quantitative estimates of mishap frequencies/likelihoods and relative importances of various accident sequences/contributing events
  3. lists of recommendations for reducing risks
  4. quantitative evaluations of recommendation effectiveness
- Quality of the evaluation depends on the quality of the system documentation, the training of the analyst, and the experience of the subject matter experts assisting the analyst

Most common uses

Generally applicable for almost every type of analysis application, but most effectively used to address the fundamental causes of specific mishaps whose risk characteristics are dominated by relatively complex combinations of events.

Only used when simpler analysis forms (such as fault tree analysis and block diagram modeling) cannot be used to model a situation appropriately.

Block Diagram Analysis



Success Paths:
- C1 working, C2 working, C3A working, C4A working
- C1 working, C2 working, C3A working, C4B working
- C1 working, C2 working, C3B working, C4A working
- C1 working, C2 working, C3B working, C4B working

Summary of Block Diagram Analysis

Deductive analysis that graphically models (using simple block diagrams) the combinations of system functions that provide successful system operations.

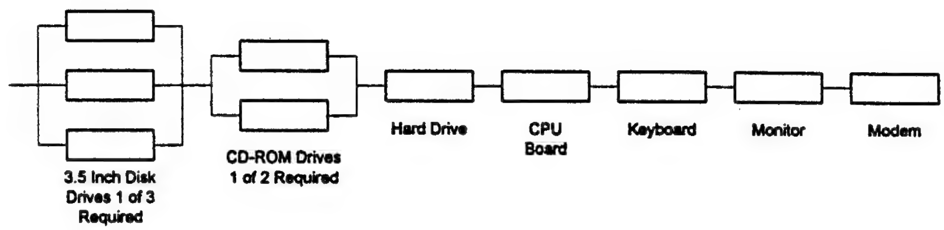
Brief summary of characteristics

- Systematic, highly structured assessment relying on the analyst's experience to generate a comprehensive review and ensure that appropriate safeguards against mishaps are in place
- Primarily performed by an individual working with system experts through interviews and field inspections
- Generates:
  1. qualitative descriptions of system functions that must be preserved to avoid mishaps
  2. quantitative estimates of mishap frequencies and relative importances of various accident sequences/contributing events
  3. lists of recommendations for reducing risks
  4. quantitative evaluations of recommendation effectiveness
- Quality of the evaluation depends on the quality of the system documentation, the training of the analyst, and the experience of the subject matter experts assisting the analyst

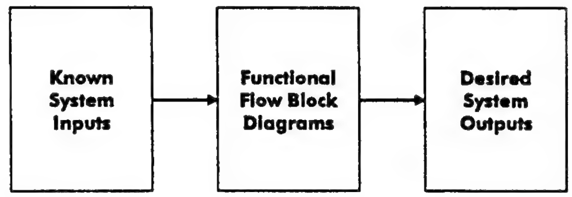
Most common uses

Generally applicable for almost every type of analysis application, but most effectively used to model the key system functions for preventing mishaps and to set loss prevention goals for various sections of a system (especially useful for systems whose risk characteristics are dominated by relatively complex combinations of events).

Example block diagram



Systems Approach to Human Element Risk Analysis



Summary of a Systems Approach to Human Element Risk Analysis

This methodology was developed as part of the Coast Guard Prevention Through People initiative and is patterned after portions of the Systems Methodology Applied to Risk Terminology (SMART) technique developed by Dr. Vernon L. Grose, D.SC., Chairman of Omega Systems Group. This systematic approach uses available historical data, employs subject matter experts, and examines operations and subprocesses as a system. This tool allows the chain of human errors to be identified and then interrupted through cost-effective prevention measures.

Brief summary of characteristics

- Systematic, highly structured assessment relying on the analyst's experience to generate a comprehensive review and ensure that sufficient human preventive actions against mishaps are in place
- Generates:
  1. qualitative descriptions of system functions that must be preserved to avoid mishaps
  2. quantitative estimates of mishap frequencies/likelihoods and relative importance of various accident sequences/contributing events
  3. lists of human preventive actions recommended for reducing risks
  4. quantitative evaluations of recommendation effectiveness
- Quality of the evaluation depends on the quality of the system documentation, the training of the analyst, and the experience of the subject matter experts assisting the analyst

The steps of the process are outlined as follows:

1. Define known inputs and desired outputs
2. Create a functional flow block diagram (FFBD)
3. Identify high-risk activities
4. Write scenarios for high-risk activities (predictive and historical)
5. Identify root causes
6. Conceive potential human element preventive actions for every risk scenario
7. Determine the full cost of every potential human element preventive action
8. Evaluate the risk control potential (high, medium, or low)
9. Recommend preventive actions for implementation
10. Approve recommended preventive actions for implementation
11. Develop and execute an implementation plan
12. Evaluate effectiveness of implemented actions

Most common uses

Generally applicable for almost every type of analysis application, but most effectively used to model the key system functions for preventing mishaps and to set loss prevention goals for various sections of a system (especially useful for systems whose risk characteristics are dominated by relatively complex combinations of events).

Example results

On the following pages are the results from a study applying this methodology for determining whether training should be considered to prevent a maritime security risk.

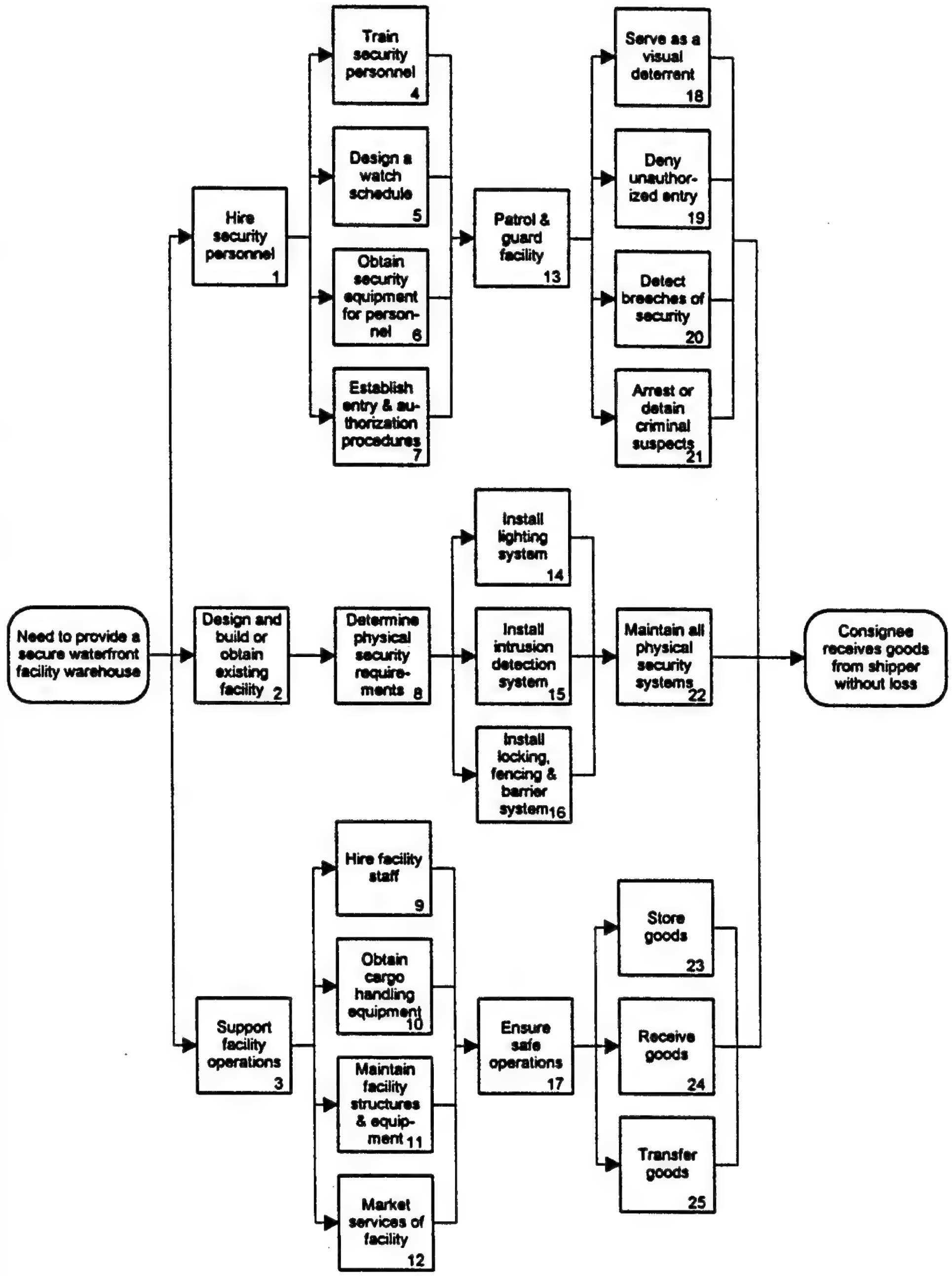
Step 1: Inputs and desired outputs for a waterfront facility warehouse security system

Known Inputs
- enclosed warehouse
- lighting system
- intrusion detection system
- locking system
- fencing system
- pilferable goods
- facility employees
- freight movers/ customers
- visitors
- unauthorized personnel
- security personnel
- security manager
- thieves with opportunity and desire to steal goods

→ **Waterfront Facility Warehouse Security System** →

Desired Outputs
- no loss of goods due to theft
- no unauthorized personnel in the facility
- high employee morale
- reputation as a well-run and secure facility
- maximum profit for company
- maximum return of client business
- attract new clients

Step 2: Functional flow block diagram for a waterfront facility warehouse security system



Step 4: Scenario for a high-risk activity

Risk Analysis Scenario Form	Scenario No. 1	FFBD No. 1	Block No. 19
Risk Scenario Description (Historical___; Predictive_X_) A warehouse is used to store portable generators, pumps, and other industrial equipment awaiting shipment. At 2 a.m., a tractor-trailer arrives. The gate guard recognizes the markings on the truck as those belonging to a carrier that does frequent business with the facility. Although entry procedures require guards to check shipping papers and verify driver identification, the guard considers this unnecessary. He is also unaware of a new policy that requires guards to record vehicle registration tags. He is extremely fatigued due to having only slept 3 hours in the last 24 due to working a second job. He waves the truck through. At 4 a.m., the truck exits the facility. Later that morning, over $100,000 worth of equipment is discovered missing.			

Step 5: Identification of root causes

Root Causes		
1. Apparent	a	Failure of guard to follow standard entry procedures after normal work hours (i.e., check shipping papers and verify identification of driver/carrier)
	b	Poor judgment exercised by guard (i.e., complacency with familiar truck company)
2. Propagating	a	Guard fatigued; slept only 3 hours in last 24
	b	Poor communication of watch standards to guards (i.e., truck's registration tags not recorded)
	c	Advanced theft techniques used against facility
	d	Warehouse left open and not staffed between 0000-0500; thieves not detected
3. Originating	a	No training provided to guards on entry procedures and importance thereof
	b	No training provided to guards on theft detection
	c	No surveillance camera system installed in warehouse
	d	Little to no supervision of security guards (i.e., fatigued security guards routinely permitted to stand watch)

Steps 6-8: Identification of potential human element preventive actions for every risk scenario, evaluation of the full cost of these actions, and evaluation of the risk control potential of these actions

Human Element Potential Preventive Actions (PA)

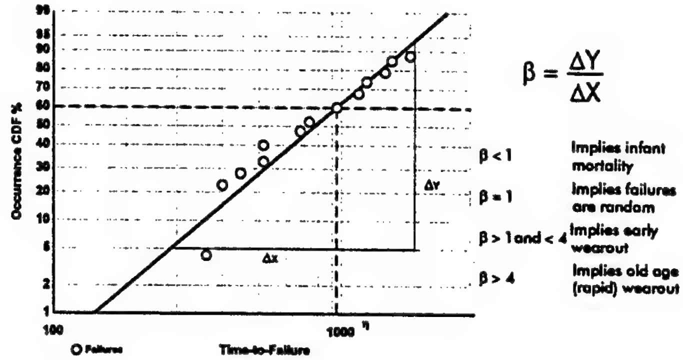
	PA No.	Cause Addressed	Action	Risk Control Potential	Cost
Management	1	1a, 1b, 2b, 2c, 3a, 3b	Require in-house training on entry procedures, security goals of the facility, and theft detection	H*, H, H	$7K
	2	2b	Establish a formal mechanism for communicating new security procedures and changes to existing watch standards (e.g., security operations manual, memos to guards)	M*, H, H	$1K
	3	2a	Develop a more flexible watch schedule to ensure that guards are rested and prepared for duty	L*, M, H	$.5K
Work environment	4	2a	Redesign guard shack to be more ergonomic and prevent fatigue	L, M, L	$30K
	5	3d	Conduct random spot checks of security guards by the security manager	M, H, H	$2K
	6	1a, 2b, 3a, 3b	Post a "security procedure of the day" board in the guard shack to enhance retention of watch standards	M, H, H	$1K
Behavior	7	1a, 3a, 3b	Require guards to pass a certification test after initial training; administer periodic "pop quizzes" thereafter to maintain qualification	H, H, H	$2K
	8	3d	Establish a reward and recognition program for security excellence	L, M, M	$1.5K
	9	2a	Establish a fitness program to keep guards in shape and alert and to reduce stress	L, M, M	$7K
Technology	10	1a	Record shipping papers and vehicle arrivals/departures using electronic scanners	M, M, L	$35K
	11	2d	Establish a "notice of arrival" signal between front gate and warehouse for carrier deliveries	M, H, M	$1.5K
	12	3c	Install remote camera system to monitor warehouse operations	M, M, L	$10K

*H = high; M = medium; L = low

Narrowly Focused, Detailed Analysis Tools

- Weibull analysis
- Human reliability analysis (HRA)
- Common cause failure analysis (CCFA)
- Sneak circuit analysis (SCA)
- Software failure analysis
- Physics-of-failure modeling
- Worker and instruction safety evaluation (WISE)

Weibull Analysis



Summary of Weibull Analysis

Failure analysis and prediction technique that statistically models component failures, even with small samples of failure data.

Brief summary of characteristics

- Used most often as a component-level analysis technique
- Quality of the evaluation largely depends on the quality of the failure data that are used. Requires data tracking (e.g., monitoring the time to failure for a specific component)
- Yields quantitative results that are graphically depicted in a Weibull chart
- Parameters from the Weibull plot can be used to help determine the failure mechanism for the component being analyzed
- Primarily performed by an individual

Most common uses

Primarily used for failure analysis of mechanical components for which good age-to-failure data are available.

Example Weibull analysis process

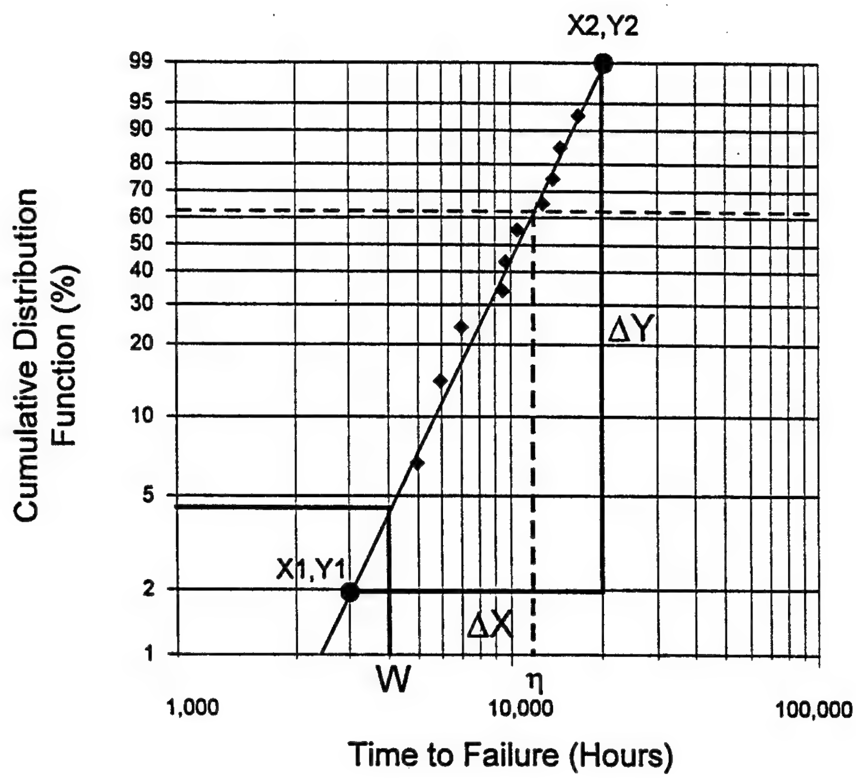
A manufacturer estimates that its customers will operate a product (a portable log splitter) for 4,000 hours per year, on average. The company wants to sell the log splitter with a 1-year warranty, but it needs to estimate the percent of returns that will be experienced in order to assess the warranty cost. The manufacturer authorizes a test program using 10 random samples of the product to begin its analysis.

Log splitter ranked times to failure

Sample Number	Rank Order(i)	Time to Failure (hours)
6	1	5,005
3	2	6,000
10	3	7,000
8	4	8,500
2	5	9,750
4	6	10,075
7	7	13,025
5	8	15,000
9	9	15,050
1	10	18,200

X-Y coordinates for Weibull plots

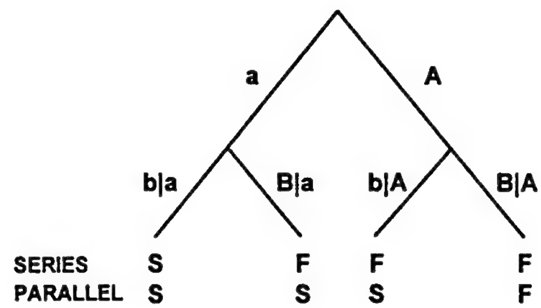
Sample Number	Rank Order(i)	X-Coordinate Time to Failure (hours)	Y-Coordinate Median Rank (percent)
6	1	5,005	6.70
3	2	6,000	16.32
10	3	7,000	25.94
8	4	8,500	35.57
2	5	9,750	45.19
4	6	10,075	54.81
7	7	13,025	64.43
5	8	15,000	74.06
9	9	15,050	83.68
1	10	18,200	93.30



The characteristic life, h, is estimated from the graph at the intercept of the plotted line and the 63.2% CDF value by dropping a vertical line to the x-axis. For the example, the characteristic life of the log splitter indicates that after approximately 12,000 hours of operation (3 years), almost two-thirds of the log splitters will have "worn out."

In addressing the manufacturer's original question, approximately 4.5% of the log splitters (determined by the Y value corresponding to 4,000 hours on the time to failure axis) will have to be replaced with new log splitters in the 4,000-hour warranty period.

Human Reliability Analysis



TASK "A" = THE FIRST TASK
TASK "B" = THE SECOND TASK
a = PROBABILITY OF SUCCESSFUL PERFORMANCE OF TASK "A"
A = PROBABILITY OF UNSUCCESSFUL PERFORMANCE OF TASK "A"
b|a = PROBABILITY OF SUCCESSFUL PERFORMANCE OF TASK "B" GIVEN a
B|a = PROBABILITY OF UNSUCCESSFUL PERFORMANCE OF TASK "B" GIVEN a
b|A = PROBABILITY OF SUCCESSFUL PERFORMANCE OF TASK "B" GIVEN A
B|A = PROBABILITY OF UNSUCCESSFUL PERFORMANCE OF TASK "B" GIVEN A

FOR THE SERIES SYSTEM:

$Pr[S] = a(b|a)$

$Pr[F] = 1 - a(b|a) = a(B|a) + A(b|A) + A(B|A)$

FOR THE PARALLEL SYSTEM:

$Pr[S] = 1 - A(B|A) = a(b|a) + a(B|a) + A(b|A)$

$Pr[F] = A(B|A)$

Summary of Human Reliability Analysis (HRA)

Specialized inductive graphical analysis tool (similar in form to fault tree analysis and event tree analysis) designed for evaluating human sequential operations. Accounts for various human errors and recovery actions as well as equipment failures.

Brief summary of characteristics

- Systematic, highly structured assessment relying on the analyst's experience to generate a comprehensive review and ensure that appropriate safeguards against mishaps are in place
- Primarily performed by an individual working with system experts through interviews and field inspections

- Generates:
  1. qualitative descriptions of potential mishaps (combinations of events producing various types of mishaps as a result of human errors at various steps of a procedure)
  2. quantitative estimates of mishap frequencies/likelihoods and relative importances of various accident sequences/ contributing events
  3. lists of recommendations for reducing risks
  4. quantitative evaluations of recommendation effectiveness
- Quality of the evaluation depends on the quality of the system documentation, the training of the analyst, and the experience of the subject matter experts assisting the analyst

Most common uses

Exclusively used for detailed evaluation of human operations (especially procedural tasks); most often used as a supplement to a broader analysis using another technique.

Best suited for situations in which complex combinations of errors/equipment failures are necessary for mishaps to occur.

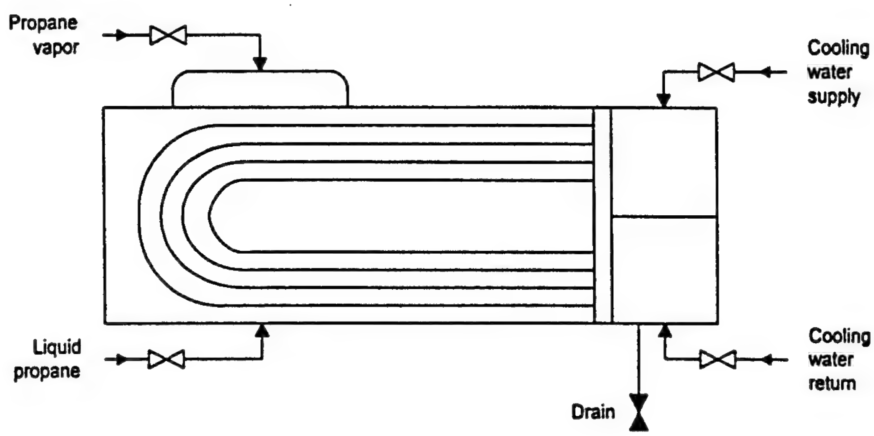
Often used in conjunction with checklist analyses that focus on specific human reliability issues such as error-likely situations.

HRA example

Assume that the system described below exists in a process unit recently purchased by your company. As the manager, the safety of this unit is now your responsibility. You are concerned because your process hazard analysis team identified the potential for an operator error to result in a rupture of the propane condenser. You have chartered an HRA to estimate the likelihood of the condenser rupturing as the result of such an error and to identify ways to reduce the expected frequency of such ruptures.

System description

Four parallel propane condensers, one of which is illustrated in the figure below, are designed with a 450-psig shell pressure rating and a 125-psig tube pressure rating. The propane vapor pressure is controlled at 400 psig; the cooling water flowing through the condenser tubes is normally maintained at 75 psig. Liquid propane flows out of the condenser as soon as it condenses; no significant inventory of liquid propane is left in the condenser. The two propane isolation valves for each condenser are rising-stem gate valves with no labels. The two water isolation valves for each condenser are butterfly valves with no labels. Their handwheel actuators have position indicators.



A tube has failed in one of the four condensers about once every 3 years. If a condenser tube fails, the affected condenser can be removed from service by closing four isolation valves (propane vapor inlet valve, liquid propane outlet valve, cooling water supply valve, and cooling water return valve). However, if a tube fails, it is essential that the operator close the two propane isolation valves before closing the two water isolation valves. Closing the two water valves first would allow pressure to build on the tube side of the condenser and rupture the tube head.

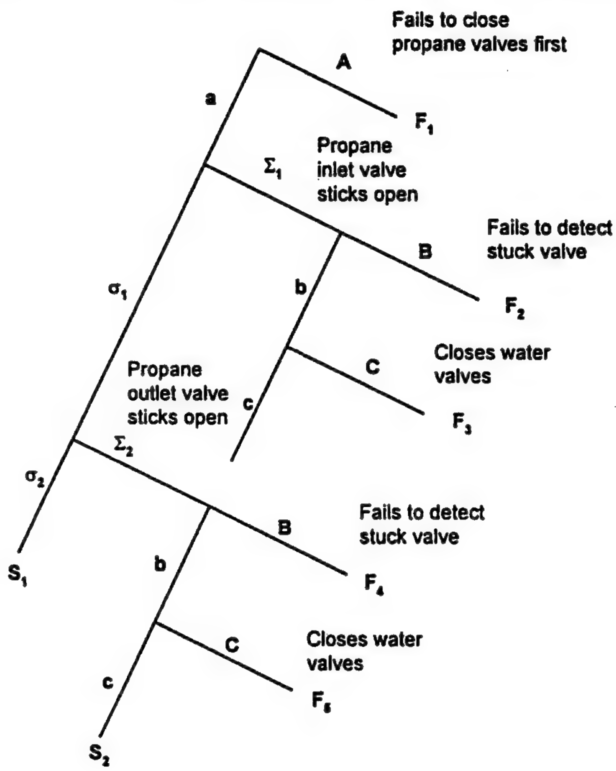
Analyzed system conditions

- A tube has failed in the condenser
- The low depropanizer pressure alarm has sounded in the control room
- The experienced field operator has observed water and gas spewing from the hydrocarbon vent at the cooling tower. The field operator shouts over the radio that a propane vapor cloud appears to be forming and moving toward the control room
- The control room operator has directed the field operator to isolate the failed condenser as quickly as possible so that a unit shutdown will not be necessary
- The operator must close the valves by hand. If a valve sticks, there is no time to go get tools to help close the valve — the process must be shut down
- The field operator has correctly identified the condenser with the failed tube by the sound of the expanding propane and the visible condensation/frost on the shell

Events included in the HRA event tree

Failure Symbol	Failure Description	Estimated Probability
A	Operator fails to close the propane valves first	0.05
Σ_1	Propane inlet valve sticks open	0.001
Σ_2	Propane outlet valve sticks open	0.001
B	Operator fails to detect a stuck valve	0.025
C	Operator chooses to close the cooling water valves to stop the propane release	0.25

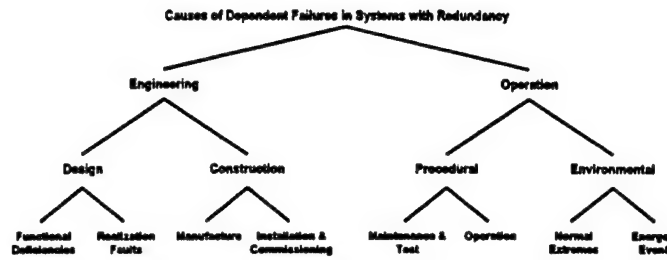
HRA event tree for improper condenser isolation



HRA results

F_1 = A	= 5.0 x 10-2
F_2 = $a\Sigma_1B$	= 2.4 x 10-5
F_2 = $a\Sigma_1bC$	= 2.3 x 10-5
F_2 = $a\sigma_1\Sigma_2B$	= 2.4 x 10-5
F_2 = $a\sigma_1\Sigma_2bC$	= 2.3 x 10-4
$F_T = F_1 + \ldots + F_5$	= 0.05

Common Cause Failure Analysis



Summary of Common Cause Failure Analysis (CCFA)

Specialized approach for systematically examining sequences of events stemming from the conduct of operations and/or operation of physical systems that cause multiple failures/errors to occur from the same root causes, thus defeating multiple layers of protection simultaneously.

Brief summary of characteristics

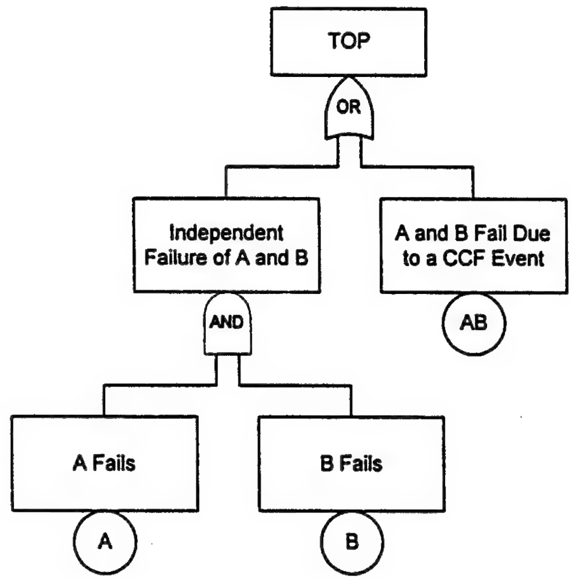
- Systematic, structured assessment relying on the analyst's experience and guidelines for identifying potential dependencies among failure events to generate a comprehensive review and ensure that appropriate safeguards against common cause failure mishaps are in place
- Used most as a system-level analysis technique
- Primarily performed by an individual working with system experts through interviews and field inspections
- Generates:
  1. qualitative descriptions of possible dependencies among mishaps
  2. quantitative estimates of dependent failure frequencies/ likelihoods
  3. lists of recommendations for reducing dependencies among failure mishaps
- Quality of the evaluation depends on the quality of the system documentation, the training of the analyst, and the experience of the subject matter experts assisting the analyst

Most common uses

Exclusively used as a supplement to a broader analysis using another technique, especially fault tree and event tree analyses.

Best suited for situations in which complex combinations of errors/equipment failures are necessary for mishaps to occur.

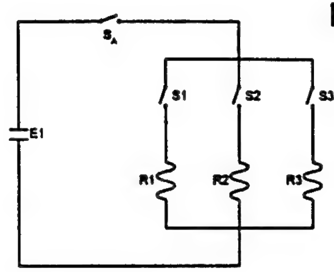
Example failure model with CCF event considerations



Guidelines on redundancy and diversity

System Type	Failure Probability Omitting CCF	Failure Probability Considering CCF
Mechanical, 1 train	10^{-2}	10^{-2}
Mechanical, 2 redundant trains	10^{-4}	10^{-3}
Mechanical, 3 redundant trains	10^{-6}	5×10^{-4}
Mechanical, 2 diverse, redundant trains	10^{-4}	2×10^{-4}
Electronic, 1 train	10^{-4}	10^{-4}
Electronic, 2 redundant trains	10^{-3}	10^{-5}
Electronic, 3 redundant trains	10^{-12}	10^{-5}
Electronic, 2 diverse, redundant trains	10^{-3}	10^{-6}

Sneak Circuit Analysis



Key terms:
- ◆ Sneak circuit
- ◆ Sneak timing
- ◆ Sneak paths
- ◆ Sneak indications
- ◆ Sneak labels
- ◆ Sneak clues

Summary of Sneak Circuit Analysis (SCA)

Inductive approaches for identifying latent paths that cause unwanted functions to occur or that inhibit desired functions in electromechanical circuits.

Brief summary of characteristics

- Systematic, structured assessment relying on analysis rules and experience of analysts to generate a comprehensive review and ensure that appropriate safeguards against mishaps are in place
- Primarily performed by an individual working with system experts through interviews and field inspections
- Generates:
  1. qualitative descriptions of circuit weaknesses
  2. statistical estimates of failure frequencies/likelihoods
  3. lists of recommendations for reducing risks
- Quality of the evaluation depends on the quality of the system documentation, the training of the analyst, and the experience of the subject matter experts assisting the analyst

Most common uses

Almost exclusively used to analyze potential failures in important (or "critical") electrical circuits. Most often used as a supplement to a broader hazard analysis using another more general technique.

Example 1: Sneak timing (digital signals)

Target: Digital Circuitry

Problem: Logic and timing errors caused by a digital signal that splits and later recombines.

Solution: Analyze the signal path through a complete cycle (e.g., on-off-on) to ensure no timing skew problems. Timing problems are eliminated by providing a clocked data buffer (e.g., latch) to sample stable data where they recombine.

Comment: Recombined paths often lead to sneak timing as a result of the logic functions performed along each path. A more commonly encountered problem is a transient signal (glitch) caused by differences in the signal propagation delay between paths. A clocked buffer reduces timing offset "skew" by resynchronizing the signals. The problem in Figure A is that a glitch occurs at the output of gate U4 during the brief interval that the skewed output signals at gates U2 and U3 are both high. The solution to this problem is shown in Figure B, where the glitch is prevented by sampling the outputs of U2 and U3 with buffer U5 after the signals have completed their transitions.

Recombining digital signals

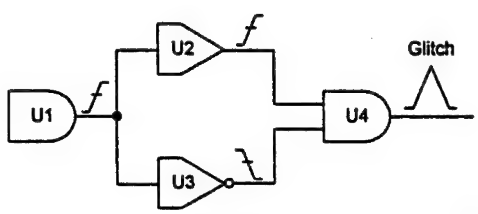


Figure A

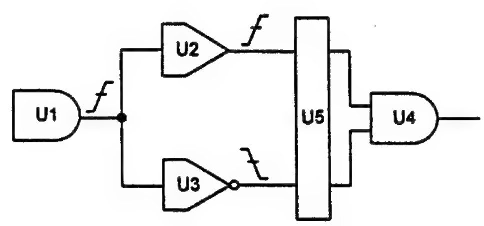


Figure B

Example 2: Sneak path (power distribution circuits)

Target: Primary and secondary power distribution circuitry made up of power sources, ground returns, switches, contacts, relays, circuit breakers, fuses, solid state switches, and/or connectors.

Problem: Asymmetrical pattern of connections for power distribution and ground return circuitry.

Solution: Use the same circuit connection topology for the supply side and ground side of a load. Use the same connector for symmetrical power and ground connections.

Comment: Circuit connection symmetry for power and ground distribution implies an identical number and location of power and ground connections feeding a load. Asymmetrical connections can cause sneak paths. The problem in Figure A is that power connection J3 has no counterpart on the ground side of load X2. If connections J2 and J3 are open while J1, J4-1, and J4-2 are closed, current can unintentionally flow in the reverse direction through X2. The solution to this sneak circuit is shown in Figure B where the problem is eliminated by the inclusion of connection J3-2.

Symmetrical power distribution

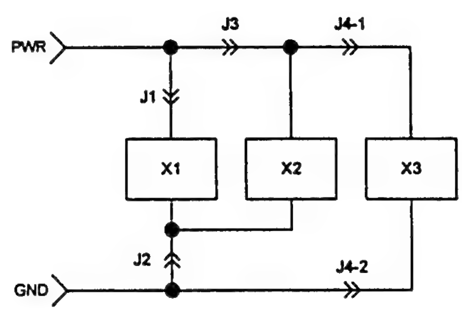


Figure A Problem

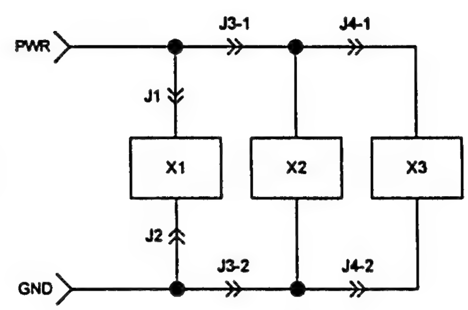
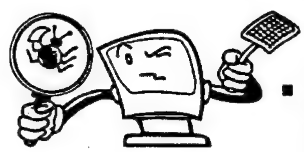


Figure B Solution

Software Failure Analysis



- Traditional — techniques such as
  - fault tree analysis
  - FMEA
  - review of procedures
- Specialized — numerous models for predicting and estimating software reliability (typically based on data from fault detection activities)

Summary of Software Failure Analysis

Assortment of tools for managing software development and predicting software reliability.

Brief summary of characteristics

- Structured guidelines and experience of analysts generate reviews of software products in varying levels of detail and ensure that appropriate safeguards against undesirable events are in place
- Primarily performed by an individual working with software experts through interviews and source code reviews
- Generates:
  1. qualitative descriptions of software weaknesses
  2. statistical estimates of failure frequencies/likelihoods for software modules
  3. lists of recommendations for reducing risks
- Quality of the evaluation depends on the quality of the software documentation, the training of the analyst, and the experience of the subject matter experts assisting the analyst

Most common uses

Exclusively used to analyze potential failures in important (or "critical") software modules. Most often used as a supplement to a broader analysis using another more general technique.

Software reliability prediction models

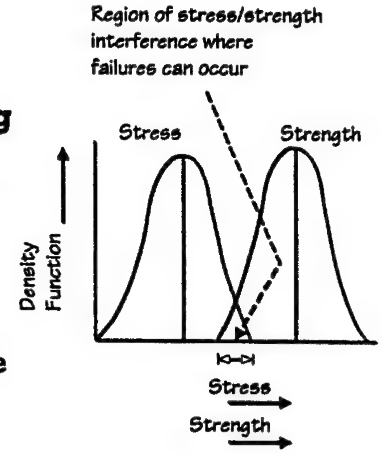
- Rome Laboratory TR-92-52
- Rome Laboratory TR-92-15
- Musa's Execution Time Model
- Putnam's Model
- Historical Data Collection

Software reliability estimation models

- Fault Count
  - Exponential
  - Shooman Model
  - Lloyd-Lipow Model
  - Musa's Basic Model
  - Musa's Logarithmic Model
  - Goel-Okumoto Model
- Historical Data Collection Model
- Raleigh Models
  - Schnick-Wolverton Model
- Weibull Models
- Test Coverage Models
  - IEEE Test Coverage Model
  - Leone's Test Coverage Model
  - Test Success Model
- Tagging Models
  - Seeding
  - Dual Test Group Model
- Bayesian Models
- Thompson and Chelson's Model

Summary of Physics-of-Failure Modeling

- Understand and operate within useful life
- Find ways to extend useful life



Summary of Physics-of-Failure Modeling

Defines relationships between key technical parameters associated with components (e.g., number of cycles, stress loads, exposures to energy sources, contact with various materials) and reliability-related characteristics (particularly time to failure).

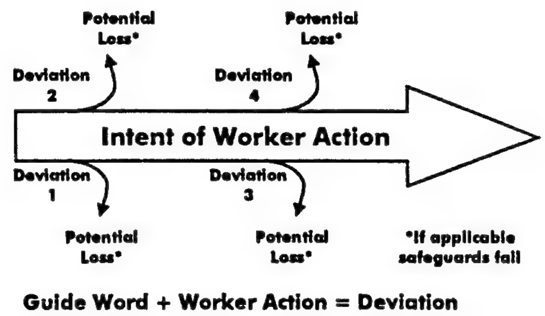
Brief summary of characteristics

- Highly technical in nature
- Primarily useful to designers, but can be beneficial to groups monitoring equipment performance (operators, maintenance technicians, inspectors, etc.)
- Addresses a wide range of technical topic areas and disciplines (mechanics, electronics, structures, etc.)
- Provides insight into how to avoid failures, but does not directly produce recommendations
- Quality of models depends on technical understanding of the physics affecting failures

Most common uses

Used in virtually all industries for establishing design guidelines and guidelines for monitoring/extending field use of equipment.

Worker and Instruction Safety Evaluation



Summary of Worker and Instruction Safety Evaluation (WISE)

A specialized form of HAZOP analysis for analyzing human activities through the use of guide words customized for human factors issues, including issues historically addressed through job task analysis.

Brief summary of characteristics

- Systematic, highly structured assessment relying on WISE guide words and team brainstorming to generate a comprehensive review and ensure that appropriate safeguards against mishaps are in place
- Typically performed by an interdisciplinary team with diverse backgrounds/experience participating in group review meetings of system documentation and field inspections
- Generates qualitative descriptions of potential mishaps (deviations, causes, consequences, and safeguards) as well as lists of recommendations for reducing risks
- Quality of the evaluation depends on the quality of the system documentation, the training of the review team leader, and the experience of the review team

Most common uses

Exclusively used for detailed evaluation of human operations (especially procedural tasks); most often used as a supplement to a broader hazard analysis using another technique.

Best suited for situations where relatively simple combinations of errors/equipment failures are necessary for mishaps to occur.

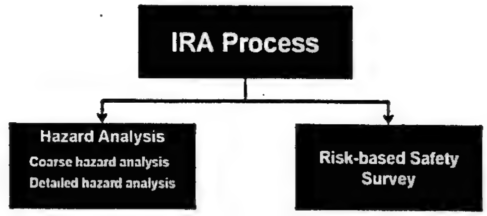
Often used in conjunction with checklist analyses that focus on specific human reliability issues such as error-likely situations.

Example results

Job Step	WISE Guide Words	Potential Consequences	Protection	Suggested Improvements
1	Skip	Debris in eye (Step 4) Asphyxiation (Step 4) Cylinder movement (Step 4)	Safety glasses Room ventilation Cylinder chained to rack Cracking open connection (Step 3)	
	Less	See Skip		
	Contact with	Burned by steam	Insulated piping	
2	Skip	Debris in eye (Step 4) Toxic exposure (Step 3) Flammable release with possible fire (Step 4) Struck by pigtail (Step 4)	Safety glasses Fire extinguishers Fire brigade Cracking open connection (Step 3)	Wear respiratory protection when breaking connection. Install check valve at catalyst pot
	Less	See Skip		
	Contact with	Burned by steam	Insulated piping	
3	More	Debris in eye	Safety glasses	
	Out of sequence	See Skip – Step 1 or 2		
	Caught between	Hand pinched between wrench and cylinder	Gloves	
	Slip	Wrench dropped	Safety shoes	Tether a wrench near the cylinder so it cannot hit the worker's foot
	Exposure to	Catalyst backflow (See Skip – Step 2)		
	Tools	Adjustable wrench slips off nut		Tether a correct-size wrench near the cylinder
4	Caught between	Hand pinched between wrench and cylinder	Gloves	
	Struck by	Debris from connection or line Pigtail whipping Cylinder falling over	Safety glasses Cracking open connection (Step 3) Cylinder chained to rack	Install check valve at catalyst pot
	Slip	Wrench dropped	Safety shoes	Tether a wrench near the cylinder so it cannot hit the worker's foot
	Exposure to	Asphyxiation (See Skip - Step 1) Catalyst backflow (See Skip - Step 2)		
	Tools	Adjustable wrench slips off nut		Tether a correct-size wrench near the cylinder

United States Coast Guard
IRA Manual

Section 4
Overview of the IRA Process



Overview of the IRA Process

The Coast Guard Integrated Risk Assessment (IRA) process provides the Coast Guard with the means to effectively manage and control loss exposure and risk at its units, and provides risk-based information to aid Coast Guard personnel in making tactical as well as long-term strategic decisions.

This overview is divided into three sections:

Introduction to the IRA Process — a brief explanation of the process, its purpose and benefits, how it will affect current Coast Guard activities, and its development and testing

Exploring the Key Results of the IRA Process — a brief explanation of the key results, who will use the results, and how they will use the results

Understanding the IRA Process — a brief explanation of the basic strategy, key participants, key elements, and interfaces with other Coast Guard programs/processes

Introduction to the IRA Process

- What is the IRA process?
- Why does the Coast Guard need the IRA process?
- What benefits will the Coast Guard receive from the IRA process?
- How will the IRA process change current Coast Guard activities?
- How was the IRA process developed?
- Has the IRA process been tested?

Introduction to the IRA Process

What is the IRA process?

The IRA process is a proactive, systematic approach for understanding the risk associated with Coast Guard activities and preventing potential mishaps within the Coast Guard by:

- Identifying how inherent hazards associated with Coast Guard operations/facilities can produce potential mishaps
- Characterizing the risks of the potential mishaps
- Assessing the types/levels of safeguards needed to effectively manage the identified risks
- Ensuring that safeguards adopted by the Coast Guard are effectively implemented in the field
- Developing recommendations for reducing risks (i.e., improvements to operations/facilities)
- Producing risk profiles for operations/facilities that Coast Guard managers can use to manage Coast Guard risks
- Providing risk-based information to aid in Coast Guard decisions

Why does the Coast Guard need the IRA process?

The Coast Guard is working to improve the management and control of risk for its units while operating with limited resources. The IRA process provides a systematic, proactive approach that allows Coast Guard management the opportunity to eliminate or reduce risks to an acceptable level before accidents occur, and provides objective means to determine where the Coast Guard's limited resources should be focused to efficiently reduce risk. Also, the risk-based information available from the IRA process helps the Coast Guard better understand the implications Coast Guard decisions have on risk.

What benefits will the Coast Guard receive from the IRA process?

The Coast Guard will receive the following benefits from the IRA process:

- Effective management of risks, focusing analysis and improvement resources on the most critical areas
- Generation of cost/benefit analysis for recommendations to address the most significant risks at Coast Guard units
- Confidence that risk-based information is being systematically developed and applied to various Coast Guard decisions

How will the IRA process change current Coast Guard activities?

The IRA process is anchored on hazard analysis, which will be performed for classes of Coast Guard vessels and at Coast Guard facilities. In the future, there may be a benefit in performing a hazard analysis for each vessel and facility in the organization. Routine health, safety, and operations surveys performed by the Coast Guard will be focused on the higher risk areas to ensure the most effective use of resources. Less risk-critical areas will be surveyed on a less frequent basis. A cost/benefit analysis for implementing recommendations and deficiency resolutions will be implemented to ensure Coast Guard dollars are directed towards efficiently maximizing risk reduction. Coast Guard decision makers will have the opportunity to take advantage of the risk-based information from the IRA process when making decisions.

How was the IRA process developed?

The Coast Guard, through its Research and Development Center (RDC), initiated two efforts under the Loss Exposure and Risk Analysis Methodology (LERAM) project to improve unit risk management activities. The RDC teamed with JBF Associates, Inc. (JBFA), a consulting firm specializing in hazard and risk analysis/management. These efforts focused on:

- Developing a hazard analysis methodology for systematically identifying and characterizing the risks of potential mishaps
- Improving the Coast Guard's current safety survey practices

The RDC and JBFA researched existing Coast Guard practices and proven risk management practices throughout various industries to develop these efforts. The IRA process refines these efforts and integrates them into an effective Coast Guard risk management tool.

Has the IRA process been tested?

The complete IRA process has been tested on the WHEC-378 vessel class. In addition, multiple platforms were used during early development validation of the IRA process. Listed in the table below are the IRA processes and the various platforms used in the tests.

IRA Hazard Analysis		IRA Safety Survey
Coarse Hazard Analysis	Detailed Hazard Analysis	
WHEC-378 *MELLON*	WHEC-378 *MUNRO*, Incinerator	WHEC-378 *SHERMAN*
WLIC-160 *KENNEBEC*	WLIC-160 *KENNEBEC*, Deck Operations	—
WMEC-270 *HARRIET LANE*	WMEC-270 *HARRIET LANE*, Small Boat Operations	—
ISC Seattle	—	—
MSO New Orleans	—	—
WMEC-625 *VENTUROUS* Paragon Project	—	—
WMEC-378 *MUNRO* Exemplar Project	—	—

Exploring the Key Results of the IRA Process

- What are the key results of the IRA process?
- Who will use the results?
- How will the results be used?

Exploring the Key Results of the IRA Process

What are the key results of the IRA process?

Identification of hazards and their associated risk

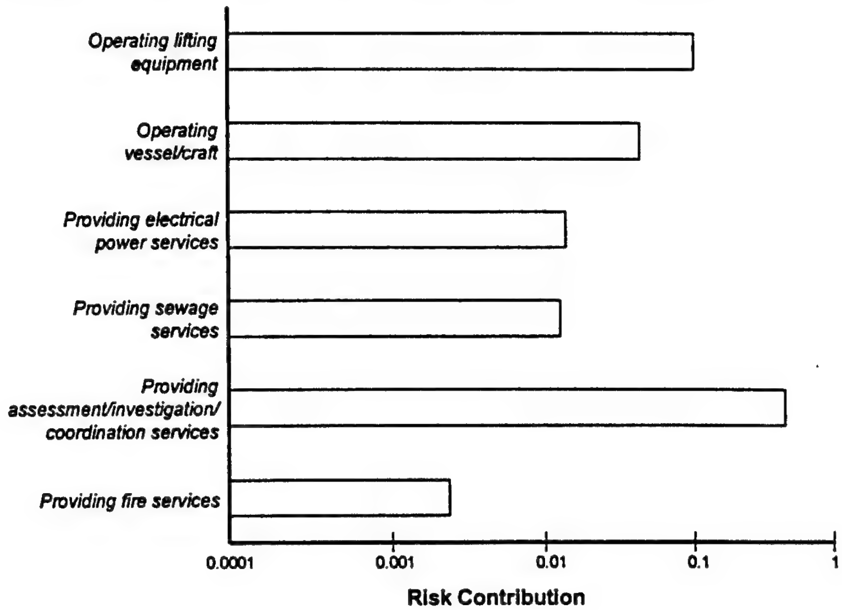
Coarse Hazard Analysis									
Operation/Evolution: Working aids to navigation									
Function: Operating lifting equipment									
			Frequency						
Deviation	Causes	Mishaps	A/B	C	D	RIN	Certainty	Safeguards	Recommendations
1.1 Loss of support	Crane cable/ rigging failure Loss of power to the crane Structural failure in buoy during lifting	Equipment damage/loss Hazardous exposure: contact injury (dropped objects, broken lines, etc.)	2	2	4	0.0063	High	Boom is inspected annually Crew inspects crane daily and cable annually	Consider a formal preventive maintenance program for crane rigging and hardware Consider further investigation of the same, particularly during loss of power

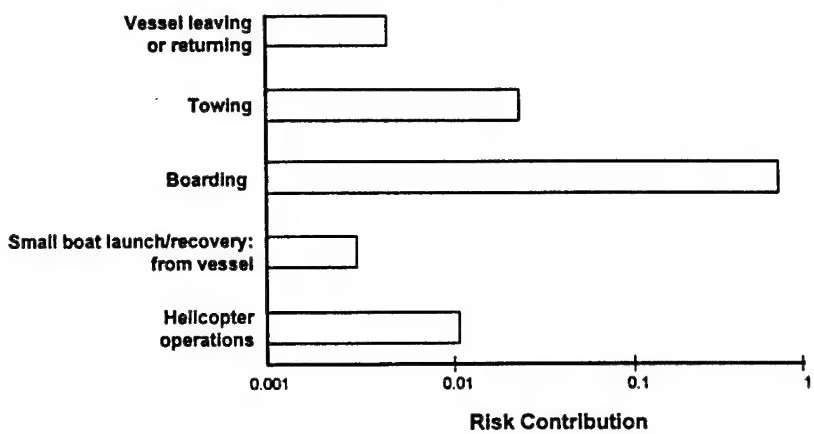
Risk matrix characterizing the platform

	A/B	C	D
Continuous (8)	0	0	0
Very frequent (7)	0	2	2
Frequent (6)	0	5	5
Occasional (5)	1	9	9
Probable (4)	2	15	22
Improbable (3)	6	14	14
Rare (2)	11	17	10
Remote (1)	36	20	3
Incredible (0)	9	4	0

Number of Mishaps

Risk ranked functions and operations/evolutions

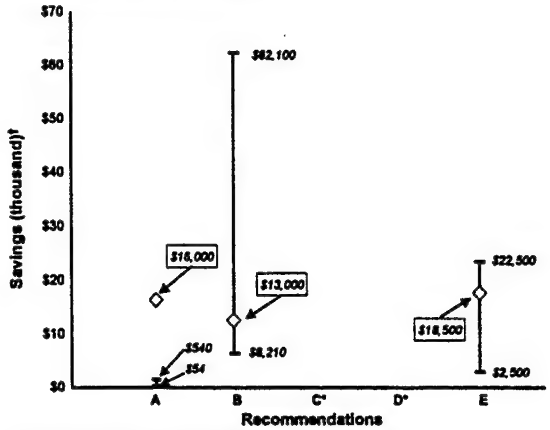




Range of mishap frequencies for assets

Vessel Class	Typical Vessel Frequency Bounds for Mishaps (per year)			Typical Vessel Expected Number of Occurrences over 50 Years			Vessel Class Frequency Bounds for Mishaps (per year)		
	A/B	C	D	A/B	C	D	A/B	C	D
Vessel Class 1	0.13 to 1.3	1.4 to 14	26 to 261	7 to 65	70 to 700	1300 to 13000	1.3 to 13	14 to 140	261 to 2610
Vessel Class 2	0.002 to 0.03	0.2 to 2	7 to 70	10% chance to 2	10 to 100	350 to 3500	0.014 to 0.21	1.4 to 14	49 to 490

Cost/benefit analysis for implementing risk reduction recommendations



*A reasonable estimate of savings is only possible after further review.
†Savings estimate assumes Class A/B mishaps cost $300,000 and Class C/D mishaps cost $30,000.
◆Estimated total cost of implementing recommendation.

Note: Savings shown account for 50-year life of a vessel.

Prioritized safety survey findings for cost/resource effective resolution

Finding	Evaluation Point	Affected Deviation (Operation/ evolution *Function* Deviation)	Baseline Frequency Scores			Revised Frequency Scores			Change in RIN	Risk Impact
			A/B	C	D	A/B	C	D		
No record of a crane inspection being performed for 2 years	N003	**Working aids to navigation** *Operating lifting equipment* Loss of support	2	3	4	5	6	7	9.0	Medium

Other key results

- Tracking of resolution of findings
- Means to measure the effectiveness of Coast Guard requirements
- Risk-based information to be used by Coast Guard decision makers

Who will use the results?

- Procurement managers
- Engineering managers
- Facilities managers
- Unit commands
- Safety professionals
- Senior management

How will the results be used?

Risk-based information from the IRA process will be used in all types of Coast Guard activities. The table on the next two pages lists Coast Guard life cycle activities. Along with each activity are uses of the IRA information and example outcomes of using the information.

Type of Activity	Use of IRA Process	Example Outcomes
Procurement	Identification of major hazards (including human factors issues) and required hazard controls while developing bid specifications for major acquisitions (e.g., new vessels or major onboard systems)	Requiring built-in redundancy for specific components of a vessel's automated navigation system
	Risk-based selection (including consideration of other factors, such as cost) among competing design alternatives for major acquisitions	Determining (and documenting) that Design A provides "best value" to the Coast Guard because it poses significantly less risk of major losses than Design B, which is slightly less expensive
Construction, Fabrication, and Commissioning	Identification of design weaknesses, safe operating limits, critical preventive maintenance tasks, human factors issues, etc., for selected systems (i.e., those that could lead to losses of interest) after the final design is complete for major acquisitions	Requiring an audible alarm and semiannual calibration of fathometers for a vessel
	Evaluation of proposed changes and identified nonconformances from the approved design	Approving a proposed field change (or a recognized nonconformance) in the routing of a high-pressure steam line because the new routing poses no identifiable increase in risks to personnel or equipment
Vessel Operations and Maintenance	Identification of precautions to be taken in performing operations outside of prescribed limits (case-by-case basis for decisions made by vessel-board personnel)	Establishing more stringent maneuvering restrictions and additional watch requirements for performing a search and rescue (SAR) operation in extreme weather conditions that would normally cause discontinuation of the operation
	Identification of precautions to be taken in preparation for performing operations when relevant vessel systems will be unavailable (case-by-case basis for operations/efficiencies identified by vessel-board personnel)	Posting additional watches and conducting special operations briefings before conducting an operation
	Evaluation of proposed changes and identified nonconformances from the standard vessel configuration (case-by-case basis for changes suggested and approved by vessel-board personnel)	Rejecting a request to temporarily store equipment on the deck while a storage locker is being replaced because the movement of the equipment under expected high seas could lead to losses of interest
	Identification of weaknesses in procedures that could lead to losses of interest (case-by-case basis for procedures developed and approved by vessel-board personnel)	Revising vague steps of a procedure (e.g., "open the valve slightly"), because a human error associated with the operation could lead to a loss of interest
Area, District, or Group Management of Operations and Maintenance	Identification of design weaknesses, safe operating limits, critical preventive maintenance tasks, human factors issues, etc., for selected systems (i.e., those that could lead to losses of interest) aboard existing ships that did not receive such reviews before being placed in operation	Recommending redesign of a small craft launching system component that could inadvertently trigger a release of a boat

Type of Activity	Use of IRA Process	Example Outcomes
Area, District, or Group Management of Operations and Maintenance (continued)	Identification of safe operating limits (from an operations/command perspective rather than a hardware system design perspective, which was addressed during design reviews) and preferred precautions to be taken if operating outside of such restrictions	Prohibiting aircraft fueling operations and other flammable material handling activities until disabled onboard firefighting systems are returned to service, but allowing emergency fueling operations if another onboard pump can be rigged to temporarily provide adequate firefighting capability
	Identification of critical training topics, standard procedures necessary, etc., for preventing losses of interest	Deciding to write a special procedure and conduct special training for the proper way to launch a new type of small craft (because the operation is significantly different from similar operations with older small craft)
	Identification of weaknesses in procedures and human factors issues that could lead to losses of interest (for standard procedures applicable to a class of vessels or the entire fleet)	Making the units of pressure referenced in a procedure (e.g., SI units) consistent with those commonly used aboard a vessel and on the vessel's gauges (e.g., English units) to help prevent confusion that could lead to an operating error
	Evaluation of proposed changes for standard vessel configurations (case-by-case basis for changes approved by group/fleet officers)	Deciding (1) against a crew reduction aboard an MEC 270 cutter because of unacceptable risks associated with degraded watch standards or (2) in favor of a crew reduction, provided that each vessel is equipped with new navigation and vessel detection systems
	Monitoring profiles of risks for classes of vessels across the Coast Guard to help understand/manage risks at a fleet level	Determining that a specific class of vessel is the next to receive a major overhaul (or replacement) program because of high loss rates
	Assigning measures of importance to safety inspection items to help prioritize responses to noted deficiencies	Deferring resolution of a few deficiencies noted during a safety inspection until next fiscal year because the deficiencies do not pose any significant risks of losses
	Risk-based selection (including consideration of other factors, such as cost) among competing alternatives such as vessel deployment, mission assignments, etc.	Deciding to send Vessel A on an extended international tour because the potential for losses associated with (1) its tour and (2) its absence from its normal station are less than those for Vessel B
Decommis-sioning	Risk-based selection (including consideration of other factors, such as cost and political pressure) among competing alternatives for vessel/station decommissioning	Deciding (and gaining support for the decision) to decommission Vessel B instead of Vessel A, even though there is some political support for keeping Vessel B in service
	Identification of weaknesses in equipment used for decommissioning and associated procedures that could lead to losses of interest	Modifying the equipment and procedures used to de-inventory hazardous materials from a vessel while the vessel is being decommissioned

Understanding the IRA Process

- What is the basic strategy?
- Who are the key participants?
- What are the key elements?
- What are the interfaces with other Coast Guard programs/processes?

Understanding the IRA Process

What is the basic strategy?

Identify hazards and their associated risk and then manage the risk with the goal of continuously reducing risk to a level acceptable for the Coast Guard

Who are the key participants?

There are four groups within the Coast Guard who will participate in the IRA process:

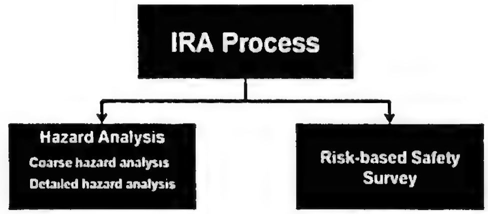
Sponsor — This individual or group of individuals (e.g., a unit commanding officer, Coast Guard management, unit safety coordinator) determines the need for the process to be performed on a particular vessel or at a particular facility. The sponsor is ultimately responsible for obtaining information from the process.

Analyst — This individual or group of individuals (e.g., MLC Health and Safety personnel, vessel safety coordinator) is responsible for performing the process on a particular vessel or at a particular facility.

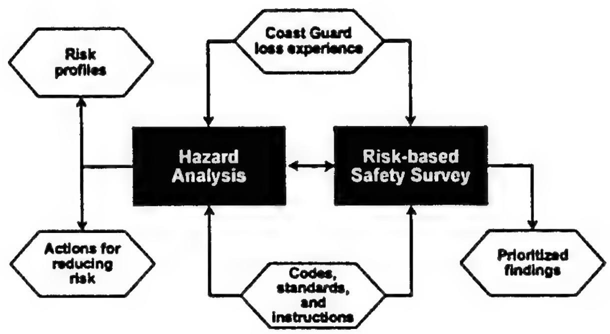
Subject matter expert — This group of individuals (e.g., vessel crew, facility staff) participates in the process by providing specific, detailed information needed to assess risks.

Decision maker — This individual or group of individuals (e.g., a unit commanding officer, Coast Guard management, Coast Guard Vessel Safety) uses the IRA process information to make risk-based decisions.

What Are the Key Elements?



The IRA process has two distinct, yet closely related, parts: (1) hazard analysis and (2) risk-based safety surveys.

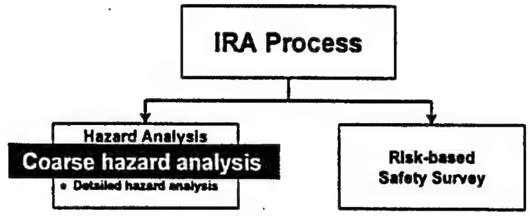


Hazard analysis

- The objectives of hazard analysis include:
  - fewer mishaps over the life of the unit
  - reduced consequences when mishaps occur
  - improved training and understanding of system interactions and the effect of the human element
  - more efficient and productive mission execution

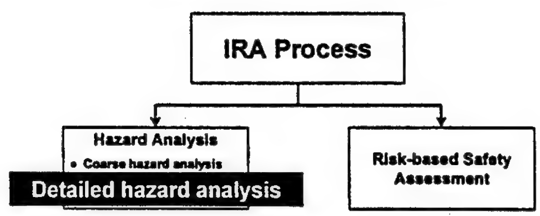
- A hazard analysis involves:
  - identifying hazards systematically
  - postulating combinations of equipment failures/human errors/external events that allow the hazards to cause mishaps
  - characterizing the risks of the potential mishaps
  - identifying the most significant contributors to risk
  - providing summaries of risk profiles associated with various assets
  - developing effective recommendations for better management of the known risks

The hazard analysis portion of the IRA process includes a set of tools for performing different types of hazard/risk analysis at various levels of detail.

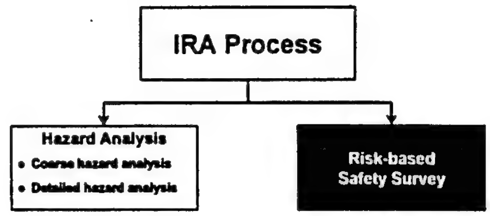


Coarse hazard analysis — Coarse hazard analysis is the cornerstone and workhorse of the hazard analysis methodology for the Coast Guard. It is designed to satisfy most of the Coast Guard's needs for hazard/risk information in a practical and efficient manner. This method provides all of the types of results of more detailed evaluations, but with a lower degree of resolution. The following are characteristics of coarse hazard analyses:

- Generally applicable to all types of Coast Guard platforms
- Capable of satisfying 60% to 90% of the Coast Guard's hazard/risk analysis needs without requiring the use of more detailed techniques
- Streamlined enough for efficient application without requiring extremely extensive evaluations
- Can be used by Coast Guard personnel with modest hazard analysis experience
- Built on solid hazard evaluation fundamentals that use not only historical perspective but also predictive reasoning



Detailed hazard analysis — Detailed hazard analysis techniques are standard industry-proven hazard/risk analysis methods providing better resolution of potential mishap scenarios and more certainty in risk characterization of mishap scenarios. For this reason, the IRA process includes an assortment of detailed hazard analysis tools that can be used for specific Coast Guard applications. These methods typically require more advanced levels of training for successful application and are used only when more detailed analysis is warranted.



Risk-based safety survey

- The objectives of a risk-based safety survey include:
  - focusing on the most significant risks
  - providing more objective prioritization of findings
  - allowing more efficient use of resources
  - resolving root causes of findings
  - developing safeguard dependability information
  - improving Coast Guard standards and requirements

- A risk-based safety survey involves:
  - focusing field observations and reviews on the most risk significant areas
  - identifying nonconformances to requirements, as well as nonconformance trends, through interviews with personnel, field observations, and documentation reviews
  - determining the underlying root cause(s) of the findings
  - prioritizing the findings and resolving higher risk findings first to efficiently and economically use resources
  - tracking the resolution of findings to ensure recommendations for correcting problems are resolved in a timely manner

Although hazard analyses are useful for determining what types and levels of protection should be in place to effectively control the risks of potential mishaps, the benefits of such analyses can be realized only if proper field implementation of the planned protections is accomplished. Risk-based safety surveys help to manage risk by ensuring requirements specifying protections/ safeguards are being implemented.

The responsibility and authority for ensuring that planned protections are in place and working effectively rests with the unit commanding officers and their staffs.

The units must understand the required protective measures and make implementation a high priority. The IRA process assumes that acceptance of this basic obligation exists and that units are conducting their own self-surveys to verify their conformance with established requirements. To help ensure that units are responsibly fulfilling their obligations and to provide units with frequent access to experts in the required protections, the IRA process includes safety surveys by third parties (e.g., Maintenance and Logistics Command [MLC] personnel independent of the unit being evaluated). These third-party surveys complement (not replace) unit self-surveys.

What are the interfaces with other Coast Guard programs/ processes?

Training program

The IRA process identifies higher risk areas that require additional training and lower risk areas where training may not be justified from a risk standpoint.

Procedure program (operational, maintenance, safety, etc.)

As with the training program, the IRA process identifies higher risk areas that require additional or modified procedures and lower risk areas where procedures or the extent of the procedures may not be justified from a risk standpoint.

Management of change/configuration management

The IRA process provides information for evaluating risk impacts of proposed changes to a system, process, or procedure.

Inspection, test, and preventive maintenance programs

The IRA process identifies and prioritizes inspection, test, and preventive maintenance activities for systems/equipment associated with higher risk scenarios.

Quality assurance programs

The IRA process identifies and prioritizes quality assurance tests necessary for systems and activities associated with higher risk scenarios.

Contingency and emergency planning

The IRA process identifies possible and most likely mishaps and their severity for use in contingency and emergency planning.

United States Coast Guard
IRA Manual

Section 5
Coarse Hazard Analysis

The IRA Coarse Hazard Analysis

- Introduction
- Performing a coarse hazard analysis
- Updating a coarse hazard analysis
- Information exchange between the coarse hazard analysis and the risk-based safety survey
- Making decisions using the coarse hazard analysis
- Evaluating change using a coarse hazard analysis

The IRA Coarse Hazard Analysis

- Introduction
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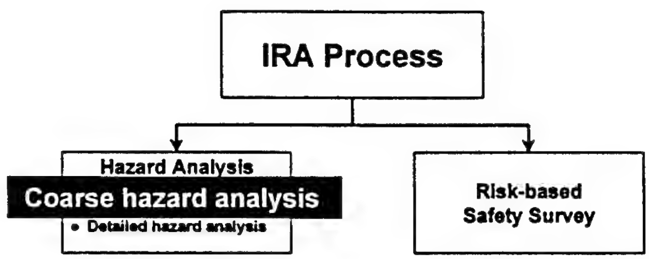
Coast Guard Coarse Hazard Analysis



The coarse hazard analysis process is designed to satisfy most of the Coast Guard's needs for hazard/risk information in a practical and efficient manner. The analysis systematically identifies risk by postulating combinations of failures, errors, and events that lead to mishaps, and characterizing the risks of those mishaps. The analysis also identifies the most significant contributors to risk, provides summaries of risk profiles for the unit class, and develops recommendations for better management of known risks.

The IRA Coarse Hazard Analysis

- Introduction
- Performing a coarse hazard analysis
- Updating a coarse hazard analysis
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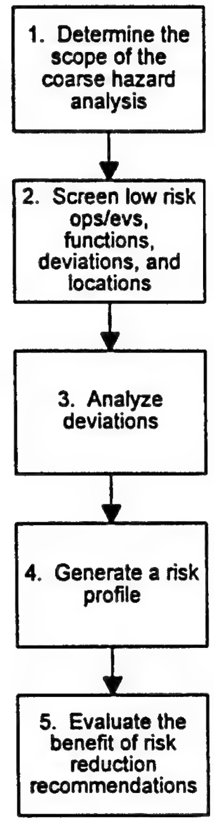
Performing a Coarse Hazard Analysis

This section describes the detailed steps involved in performing a coarse hazard analysis.



Overview of the Steps for Performing a Coarse Hazard Analysis

1. Determine the scope of the coarse hazard analysis

Determining the scope includes identifying the hazards, mishaps, operations/evolutions, functions, and locations that will be analyzed.

2. Screen low risk operations/evolutions, functions, deviations, and locations

Screening items streamlines the analysis by eliminating in-depth review of low risk items.

3. Analyze deviations

Evaluate the deviations of each function for all operations/ evolutions within the scope of the analysis.

Evaluating deviations is the fundamental activity in the coarse hazard analysis. This involves identifying mishaps, causes, and safeguards.

Characterize deviation risk

Characterizing the risk associated with deviations involves assigning risk scores, risk index numbers (RINs), and certainty of the risk estimate to each deviation.

Develop recommendations

Often, deviation risk is high or uncertain, and recommendations to lower the risk or recommendations for further analysis are necessary.

4. Generate a risk profile

Determine the risk contribution of deviations

This step explains how to identify the deviations that are the high risk contributors.

Determine the risk contribution of functions

This step explains how to determine which functions are the high risk contributors.

Determine the risk contribution of operations/evolutions

This step explains how to determine which operations/evolutions are the high risk contributors.

Determine the risk contribution of locations

This step explains how to determine which locations are the high risk contributors.

Generate a risk matrix

This step explains how to build the risk matrix. A risk matrix illustrates the distribution of deviations in various frequency categories.

Determine the unit class range of mishap frequencies

This step explains how to determine the estimated frequency of each class of mishap occurring for a unit class.

Compare frequency estimates/historical experience

Performing this step compares the estimated frequencies of mishaps with the historical Coast Guard experience.

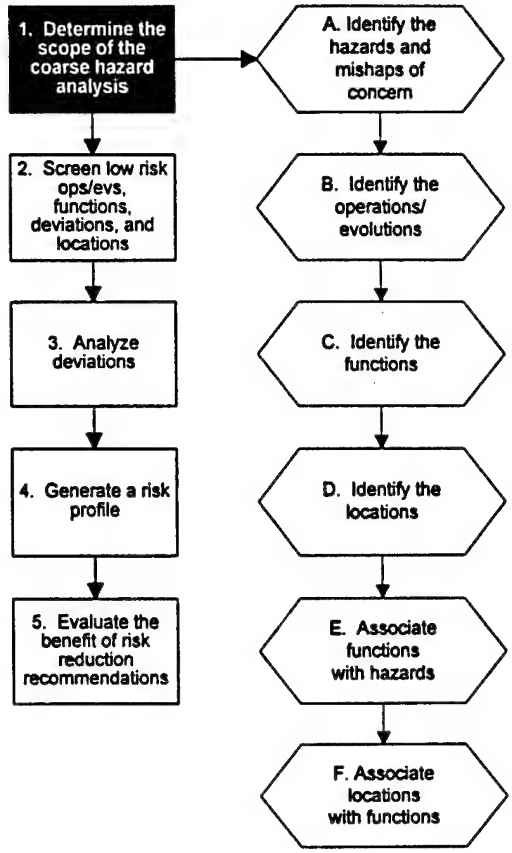
5. Evaluate the benefit of risk reduction recommendations

Determine revised frequency scores and RINs

This step explains how to determine revised frequency scores and RINs for deviations affected by the recommendation.

Determine the benefit of implementing recommendations

Performing this step involves calculating the range of estimated benefit (risk reduction) from implementing a recommendation.



Step 1 Determine the Scope of the Coarse Hazard Analysis

To determine the scope of a coarse hazard analysis, identify hazards and mishaps of concern, operations/evolutions, functions, and locations within the unit associated with the unit class under review.

Step 1.A Identify the hazards and mishaps of concern

Identifying and reviewing the hazards and mishaps of concern to the unit (or class of unit) are important to the success of the analysis. The analysis team needs a good understanding of the hazards to effectively investigate each mishap scenario.

Example: hazard – flammable materials

- Gasoline (pumps and outboard motors)
- Paint lockers (paints, thinners, etc.)
- Acetylene
- Solvents/cleaners
- Hydrogen (from batteries)

The table on the following pages is an example hazard and mishap identification guide. A guide such as this should be developed and used during the analysis.

Hazard Categories	Hazards	Vessel-specific Hazards Common to Coast Guard Vessels	Potential Mishaps of Interest
Kinetic energy	Vessel motion	Underway motion Pitch Roll	Collision with another vessel Collision with a fixed object Collision with a floating object Grounding vessel Capsizing vessel Sinking vessel Equipment damage/loss Person overboard Hazardous exposure: contact injury
	Motion of objects external to the vessel (other vessels, floating objects, helos, etc.)	Underway motion (near Coast Guard vessel/boat) Pitch (alongside Coast Guard vessel/boat) Roll (alongside Coast Guard vessel/boat)	Collision with another vessel Collision with a floating object (logs, buoys, etc.) Collision with helo Equipment damage/loss (from wake action or helo downwash) Person overboard (from wake action or helo downwash)
	Onboard equipment motion	Rotating equipment Drive trains, belts, shafting, gears, etc. Cranes Anchors Gun mounts Ammunition loaders Ground tackle Radar antennas Unsecured gear Power tools Hatches	Hazardous exposure: contact injury (broken/misoperated/unsecured equipment)
	Personnel motion	Movement on board ship	Person overboard Hazardous exposure: contact injury
Potential energy	Elevated objects	Small boats Objects held by cranes/lifts (stores, equipment, buoys, ammunition) Equipment stored on shelves Unsecured equipment (e.g., tools) on elevated platforms	Hazardous exposure: contact injury (dropped equipment) Equipment damage/loss (dropped equipment)
	Flotation	Water	Sinking vessel
	Elevated personnel	Personnel on ladders Personnel on platforms	Hazardous exposure: contact injury
	Personal flotation	Water	Drowning Hazardous exposure: contact injury
	High pressure	Compressed air system Compressed gas tanks Hydraulic systems Fire hoses	Hazardous exposure: contact injury (release of high pressure) Equipment damage/loss (release of high pressure)
	Tension/ Compression	Tow lines Mooring, intervessel tension cables, and other tension lines Spring-loaded actuators Ground tackle Lift cables/rigging	Hazardous exposure: contact injury Equipment damage/loss Capsizing vessel (towed vessel)

Hazard Categories	Hazards	Vessel-specific Hazards Common to Coast Guard Vessels	Potential Mishaps of Interest
Electrical energy	Electric power	Generators Batteries Distribution system Welding Tools/appliances	Hazardous exposure: electrical shock Fire/explosion (electrical)
	Static	Fuel lines Helo operations	Hazardous exposure: electrical shock Fire/explosion (electrical) Equipment damage/loss (electrical power deviation)
Thermal energy	Hot materials	Steam Hot water system Jacket water piping in engine room Galley Lube oil Diesel exhaust	Hazardous exposure: hot environment/ surface/material (burns) Equipment damage/loss (excessive temperature)
	Hot surfaces	Steam lines Hot water lines Heaters Motors Failed bearings Engine room surfaces Galley equipment Welding areas Guns	Hazardous exposure: hot environment/ surface/material (burns)
	Hot environments	High temperature in engine room High temperature where delicate electrical equipment is in use (e.g., CIC) High temperature on deck	Hazardous exposure: hot environment/ surface/material (heat stress) Equipment damage/loss (electrical equipment fails in high temperature environment)
	Cold materials	Autorefrigeration of compressed gases	Hazardous exposure: cold environment/ surface/material (frostbite)
	Cold environments	Low temperature on deck Low temperature water Walk-in freezer	Hazardous exposure: cold environment/ surface/material (frostbite/hypothermia)
Acoustic energy	Noise	Engine room Gunfire Pile driving Power tools	Hazardous exposure: noise (>84dB)
Hazardous materials	Flammables	Gasoline (pumps and outboard motors) Paints locker (paints, thinners, etc.) Acetylene Solvents/cleaners Hydrogen (from batteries)	Fire/explosion (flammable material)
	Combustibles	JP-5 (helo fuel) Diesel fuel oil (vessel fuel) Hydraulic fluids Lube oil Foam, plastics, etc. Oily rags, damp manila lines, etc. (spontaneous combustion)	Fire/explosion (combustible material)

Hazard Categories	Hazards	Vessel-specific Hazards Common to Coast Guard Vessels	Potential Mishaps of Interest
Hazardous materials (continued)	Explosives	Pyrotechnics Ammunition Chaff system	Fire/explosion (explosive energy release affects equipment/people)
	Toxics	Paint locker Solvents/cleaners Asbestos CFCs Lead paints Benzene in some products PCBs Combustion products from fires (particularly involving plastics, foams, insulations, etc.) Hypochlorite and bromine (water treatment) Confiscated materials Chemical locker in engine rooms	Hazardous exposure: toxic/corrosive materials
	Reactives	OBA canisters (internal reaction) Pyrotechnics (with salt water)	Fire/explosion (violent reaction between pyrotechnics and salt water)
	Corrosives	Battery acid Hypochlorite and bromine (water treatment) AFFF Spent OBA canisters PKP	Hazardous exposure: toxic/corrosive materials (release of corrosive material)
	Asphyxiants	Halon CO_2 Refrigerants Nitrogen Potentially oxygen-deficient atmospheres (confined spaces, especially where painting is occurring) Combustion products (CO and CO_2) Steam	Hazardous exposure: asphyxiants (people suffer oxygen deprivation)
	Biological materials	Infectious disease	Hazardous exposure: biological materials (infectious diseases)
Radiation	Nonionizing radiation	Radar HF communications	Hazardous exposure: radiation (nonionizing)
Weapons	Guns	Small arms Large caliber weapons	Firearm discharge Fire/explosion (explosion inside of weapon)

Step 1.B Identify the operations/evolutions performed by the vessel being analyzed

***Operation/evolution** — a specific operational mode of a Coast Guard vessel/facility.*

The current set of operations/evolutions is maintained separately from this handbook by the Coast Guard. The operations/evolutions applicable to the unit (or class of unit) being analyzed and of interest in the analysis should be chosen from this set.

Note:
*An analysis may be focused on one or more operations/evolutions (e.g., **boarding** and **towing**) while disregarding the other operations/evolutions.*

Example operations/evolutions:

- **Boarding**
- **Towing**
- **Working aids to navigation**
- **Damage control**

Note:
Operations/evolutions in this manual are in bold type.

Tip:
See Section 9 for the current list of Coast Guard operations/evolutions.

Step 1.C Identify the functions applicable to the operations/evolutions being analyzed

Function *— a distinct activity that supports one or more operations/evolutions*

Example functions:

- *Operating vessels/craft*
- *Operating lifting equipment*
- *Providing electrical power*

Note:
Functions listed in this manual are in italicized type.

Identify the functions that are applicable to the operations/evolutions and unit (or class of unit) being analyzed. The current set of functions is maintained separately from this handbook by the Coast Guard.

Example:

Operation/ evolution	Functions
Towing	*Operating vessels/craft*
	Operating deck equipment

Note:
It is possible that the analysis scope may not include all possible functions for a given operation/evolution. For example, an analysis may only investigate flammable liquid releases. Therefore, the function providing potable water services *would not be included in the analysis. Or the analysis may be for a patrol boat and the function* operating aircraft *would not be applicable.*

Identifying the operations/evolutions and associated functions provides a road map for completing the coarse hazard analysis.

Tip:
See Section 9 for the current list of Coast Guard functions. Included in Section 9 is a guide for understanding functions.

Step 1.D Identify the locations of the unit applicable to the operations/evolutions and functions being analyzed

***Location** — a distinct area of a unit where an operation/evolution is performed*

Define locations as generally as possible. However, some locations may be very specific (e.g., forward sewage compartment) to effectively perform the coarse hazard analysis.

Example locations:
- Berthing areas
- Medical
- Galley
- Engine room

Step 1.E Associate functions with hazards

There are hazards associated with each function. Associating hazards with functions identifies the specific hazards and mishaps the analysis team should be considering as a function is analyzed.

Example: *operating lifting equipment*

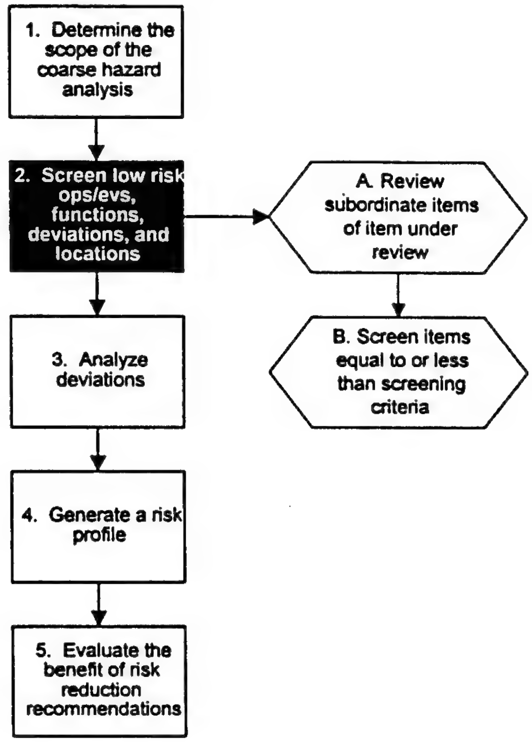
Function	Hazard	Vessel-Specific Hazard
Operating lifting equipment	Elevated objects	Small boats Objects held by cranes/lifts (stores, equipment, buoys, ammunition) Equipment stored on shelves Unsecured equipment (e.g., tools) on elevated platforms
	Tension/compression	Lift cables/rigging
	Elevated personnel	Personnel on ladders Personnel on platforms
	High pressure	Hydraulic systems
	Onboard equipment motion	Rotating equipment Drive trains, belts, shafts, gears, etc. Cranes

Step 1.F Associate locations with functions

There are locations in the unit associated with performing a function. The analysis team needs an awareness of the different locations to ensure that all hazards and potential mishaps are addressed when analyzing a function. Also, different locations will contribute different amounts of risk when performing the same function, and those differences are important when managing the risk of the unit.

Example: galley

Location	Functions
Engine room	*Operating vessels/craft*
	Operating lifting equipment
	Providing electrical power services
	Providing fire services



Step 2 Screen Low Risk Operations/Evolutions, Functions, Deviations, and Locations

***Screening** — determining at a high level that an item is of low risk and will not need to be analyzed in detail*

Screening items allows the analysis team to streamline the coarse hazard analysis process by identifying low risk items and screening them from the analysis. Screening is a systematic activity that can be performed at any stage of the analysis process from evaluating operations/evolutions to locations. Screening is based on the following relationships:

operations/evolutions consist of *functions*
functions consist of deviations
deviations occur in locations

where,

functions are subordinate to **operations/evolutions**
deviations are subordinate to *functions*
locations are subordinate to deviations

The steps below outline the screening process. These steps should be used during the various stages of the analysis.

Step 2.A Qualitatively review the subordinate items that are a part of the item under review

For example, review all of the deviations and associated locations that are a part of a function when considering whether to screen the function. This is a high level review of the subordinate items that is performed to familiarize the analyst just enough to make a high level estimate of mishap frequency in the next step. This review may not involve much more than identifying the subordinate items. Detailed analysis will follow later in the analysis sessions.

Step 2.B Screen the item if it is estimated to have frequency scores equal to or less than the screening criteria with at least a Medium certainty

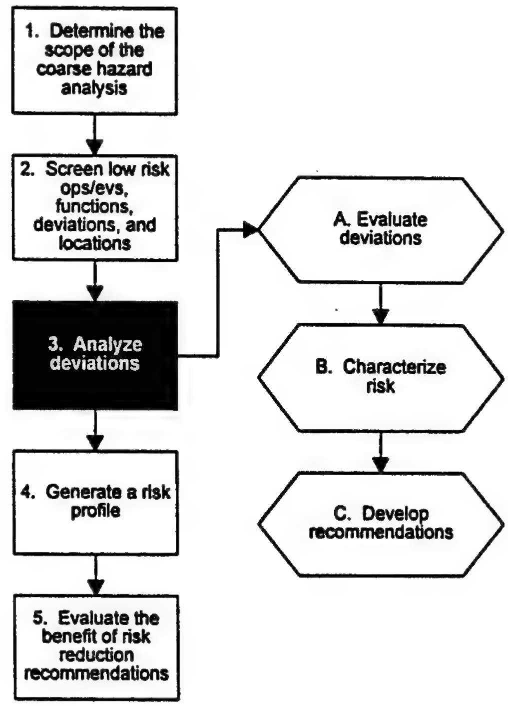
After reviewing the subordinate items, determine whether their collective frequency scores are less than or equal to the screening criteria. Remember that this is a high level qualitative estimate. Detailed analysis will follow if the item is not screened.

Note:
If any of the mishap frequencies of the subordinate items are estimated to be higher than the screening criteria, the item under review should not be screened.

The screening criteria are defined by Coast Guard management systems and are the level of risk (frequency of occurrence of a Class A/B, C, or D mishap) that the Coast Guard is not willing to pursue for further analysis.

IMPORTANT!

The screening process should be applied to all operations/evolutions at the beginning of the analysis. The set of nonscreened operations/evolutions will be assessed once all operations/evolutions are assessed. As each operation/evolution is investigated, the screening process should be applied to function, deviation, and location as they are analyzed.



Step 3 Analyze Deviations

Coarse hazard analysis provides a systematic way to analyze potential mishaps by identifying deviations to the design intent of a function, their causes, their potential mishaps, and the safeguards in place to prevent the causes or mitigate the mishaps. The analysis also defines the risk associated with the deviations as well as recommendations to reduce the risk.

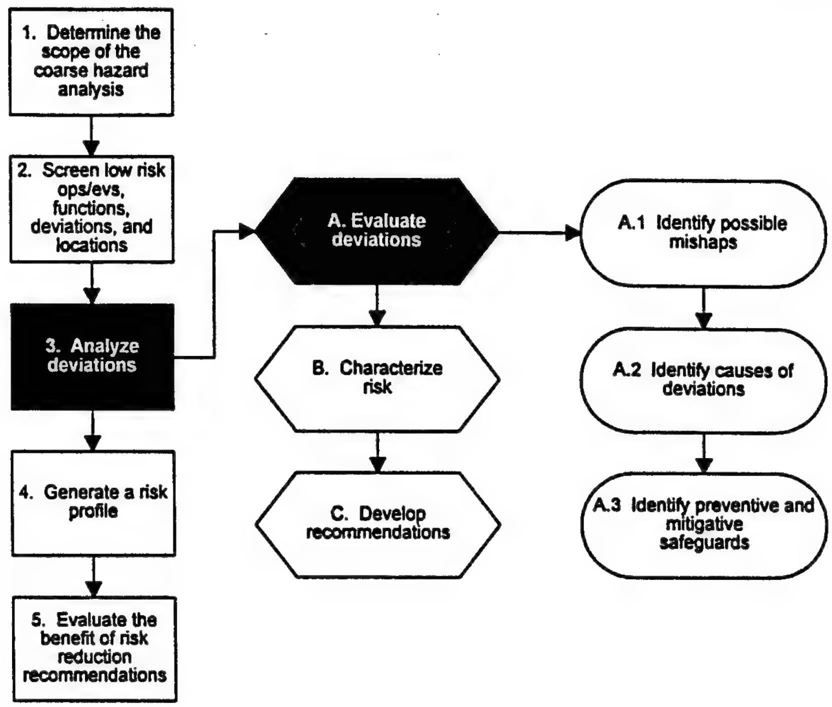
This section presents the method for documenting the analysis and explains the detailed steps for identifying and characterizing potential mishaps by evaluating deviations, characterizing deviation risk, and developing recommendations.

The analysis documentation table

Typically, analysis software will be used to collect the analysis data. However, the coarse hazard analysis can be documented using a table such as the one on the following page. The table arranges the information in a logical format and allows flexibility in reporting when captured electronically. Within the scope of the analysis, the table includes the operations/evolutions applicable to the unit class analyzed, the functions applicable to each operation/evolution, and the deviations associated with each function. Each deviation is evaluated during the analysis, completing the analysis table.

Coarse Hazard Analysis of WHEC-378											
Operation/evolution: Towing											
Function: Operating vessels/craft											
				Freq.							
No.	Deviation	Causes	Mishaps	A/B	C	D	RIN	Certainty	Safeguards	Recommend-ations
1.1	Incorrect position/ direction/ speed	Mechanical failure of steering system Mechanical failure of main diesel engine Officer of the deck chooses/orders wrong vessel course	Collision with a fixed object Collision with another vessel Grounding vessel	3	4	3	0.0603	High	PQs for bridge watch-standers Preventive maintenance on the engines	Consider performing preventive maintenance on the steering system
1.2	Vessel struck by another vessel	Tow line is too short Mechanical failure of main diesel engine Towed vessel maneuvers incorrectly	Collision with another vessel	2	3	4	0.009	High	PQs for bridge watch-standers Preventive maintenance on the engines	

Along with the analysis table (or software tool), it is good practice to have a means to record notes or comments pertaining to the information in the table.



Step 3.A Evaluate Deviations

Coarse Hazard Analysis of WHEC-378										
Operation/evolution: Towing										
Function: Operating vessels/craft										
				Freq.						
No.	Deviation	Causes	Mishaps	A/B	C	D	RIN	Certainty	Safeguards	Recommend-ations
1.1	Incorrect position/ direction/ speed	Mechanical failure of steering system Mechanical failure of main diesel engine Officer of the deck chooses/orders wrong vessel course	Collision with a fixed object Collision with another vessel Grounding vessel	3	4	3	0.0603	High	PQs for bridge watch-standers Preventive maintenance on the engines	Consider performing preventive maintenance on the steering system

***Deviation** — an off-normal condition or situation that has the potential to result in a mishap*

A coarse hazard analysis is performed by systematically evaluating deviations listed in the analysis tables.

Tip:
See Section 9 for the current list of deviations for each function. Included in Section 9 is a guide for understanding deviations.

IMPORTANT!

Before analyzing deviations, consider at a high level all of the deviations that are a part of the function being analyzed. Determine whether the function can be screened.

For each deviation, consider at a high level the locations associated with the deviation to determine whether the deviation can be screened.

Steps used to evaluate a deviation

3.A.1 Identify possible mishaps of the deviations

3.A.2 Identify causes of the deviations

3.A.3 Identify preventive and mitigative safeguards

Step 3.A.1 Identify possible mishaps of the deviations

Coarse Hazard Analysis of WHEC-378										
Operation/evolution: Towing										
Function: Operating vessels/craft										
				Freq.						
No.	Deviation	Causes	Mishaps	A/B	C	D	RIN	Certainty	Safeguards	Recommend-ations
1.1	Incorrect position/ direction/ speed	Mechanical failure of steering system Mechanical failure of main diesel engine Officer of the deck chooses/orders wrong vessel course	Collision with a fixed object Collision with another vessel Grounding vessel	3	4	3	0.0603	High	PQs for bridge watch-standers Preventive maintenance on the engines	Consider performing preventive maintenance on the steering system

***Mishap** — a potential result of a deviation*

For Coast Guard purposes, a mishap is any result of a deviation that can produce a Class A, B, C, or D mishap of interest. Class A, B, C, and D mishaps are defined as follows:

Mishap Severity Category	Description*
Class A	• The cost of reportable property damage is $1,000,000 or more • A vessel is missing or abandoned, recovery is impossible or impractical, the vessel cannot be repaired economically • An injury or illness results in a fatality or permanent total disability
Class B	• The resulting cost of reportable property damage is $200,000 or more, but less than $1,000,000 • Any injury and/or illness results in permanent partial disability • Five or more people are inpatient hospitalized
Class C	• The cost of property damage is $10,000 or more, but less than $200,000 • A nonfatal injury or illness that results in any loss of time from work beyond the day or shift on which it occurred
Class D	• The cost of property damage is $1,000 or more, but less than $10,000 • A nonfatal injury or illness occurs that does not meet the criteria of a Class C mishap • A person is overboard, an accidental firearms discharge occurs, or an electric shock occurs that does not meet the criteria of a higher classification

* The mishap terminology is consistent with listings in the MISREP database.

The set of Coast Guard mishaps of interest include:

Mishaps of Interest*

Capsizing vessel	Person overboard
Collision with another vessel	Hazardous exposure: contact injury
Collision with a fixed object	Hazardous exposure: toxic/corrosive materials
Collision with a floating object	Hazardous exposure: electrical shock
Collision with helo	Hazardous exposure: cold environment/ surface/material
Grounding vessel	Hazardous exposure: hot environment/ surface/material
Sinking vessel	Hazardous exposure: asphyxiants
Fouled screw	Hazardous exposure: noise
Fire/explosion	Hazardous exposure: radiation
Firearm discharge	Hazardous exposure: biological materials
Equipment damage/loss	
Loss of small boat	
Loss of helo	
Drowning	

* The mishap terminology is consistent with listings in the MISREP database.

Step 3.A.2 Identify causes of the deviations

Coarse Hazard Analysis of WHEC-378										
Operation/evolution: Towing										
Function: Operating vessels/craft										
				Freq.						
No.	Deviation	Causes	Mishaps	A/B	C	D	RIN	Certainty	Safeguards	Recommendations
1.1	Incorrect position/ direction/ speed	Mechanical failure of steering system Mechanical failure of main diesel engine Officer of the deck chooses/orders wrong vessel course	Collision with a fixed object Collision with another vessel Grounding vessel	3	4	3	0.0603	High	PQs for bridge watch-standers Preventive maintenance on the engines	Consider performing preventive maintenance on the steering system

***Cause** — an event, that if not mitigated, results in a mishap*

Causes of deviations can be:

- Human error
- Equipment failure
- Hardware system failure
- Administrative system failure

Focus on single event causes. Include multiple event causes only in cases where the frequency of the multiple events occurring is high.

Note:
When answering this question, only consider the operation/evolution currently under review.

Remember that this is a coarse hazard analysis. Avoid getting too detailed. Try to focus at the system level initially. However, if the risk associated with the deviation is high, more detail may be warranted.

Step 3.A.3 Identify preventive and mitigative safeguards

Coarse Hazard Analysis of WHEC-378										
Operation/evolution: Towing										
Function: Operating vessels/craft										
				Freq.						
No.	Deviation	Causes	Mishaps	A/B	C	D	RIN	Certainty	Safeguards	Recommend-ations
1.1	Incorrect position/ direction/ speed	Mechanical failure of steering system Mechanical failure of main diesel engine Officer of the deck chooses/orders wrong vessel course	Collision with a fixed object Collision with another vessel Grounding vessel	3	4	3	0.0603	High	PQs for bridge watch-standers Preventive maintenance on the engines	Consider performing preventive maintenance on the steering system

***Safeguard** — engineered systems (hardware) or administrative controls for reducing the frequency of occurrence or mitigating the severity of deviations*

Answer this question when identifying safeguards:

"While performing this operation/evolution, what are the engineered or administrative systems in place to reduce the frequency of the deviation(s) or reduce the severity of the deviation(s)?"

Answer this question with respect to the operation/evolution being considered.

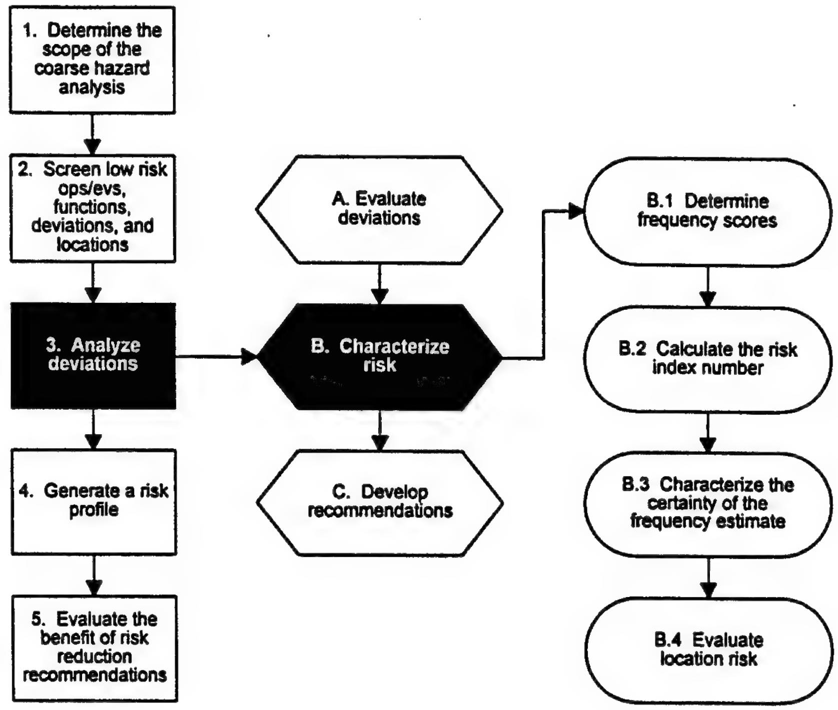
Types of safeguards to consider:

- Hardware (e.g., barriers, alarms, interlocks, redundant pumps)
- Specific procedures and training (e.g., ammunition loading procedure, PQS for deck crew)
- Specific administrative policies (e.g., respirator program)

Avoid becoming too optimistic about safeguard reliability/ effectiveness. If the dependability of a safeguard is in question, the conservative approach is to not take credit for it (especially human detection/response and adherence to administrative policies).

Think about each deviation as a mishap scenario.

- Each cause is an initiating event.
- Safeguards are the engineered features or actions that make deviations less likely and/or reduce the severity of the mishap.



Step 3.B Characterize the risk of deviations

***Risk** — the combination of the expected frequency (events/year) and consequence (effects/event) of a single accident or group of accidents.*

For each deviation, the risk associated with the deviation's possible outcomes (mishaps) must be characterized. This characterization includes frequency and consequence estimates, a risk index number derived from the frequency estimates, and determination of the certainty of the estimate.

The risk associated with a location will also be determined in this section.

Steps used to characterize risk

3.B.1 Determine frequency scores
3.B.2 Calculate the risk index number
3.B.3 Characterize the certainty of the frequency estimate
3.B.4 Evaluate location risk

Step 3.B.1 Determine the frequency of deviations resulting in Class A/B, C, and D mishaps

Coarse Hazard Analysis of WHEC-378										
Operation/evolution: Towing										
Function: Operating vessels/craft										
				Freq						
No.	Deviation	Causes	Mishaps	A/B	C	D	RIN	Certainty	Safeguards	Recommend-ations
1.1	Incorrect position/ direction/ speed	Mechanical failure of steering system Mechanical failure of main diesel engine Officer of the deck chooses/orders wrong vessel course	Collision with a fixed object Collision with another vessel Grounding vessel	3	4	3	0.0603	High	PQs for bridge watch-standers Preventive maintenance on the engines	Consider performing preventive maintenance on the steering system

***Frequency** — a score indicating the expected number of occurrences per year of the relevant mishap class*

***Class A/B Mishap** — a mishap that is categorized as Class A or Class B. For the purposes of risk calculations, Class A/B mishaps are equivalent to a loss of $200,000 or greater (average loss of $300,000)*

***Class C Mishap** — a mishap that is categorized as Class C. For the purposes of risk calculations, Class C mishaps are equivalent to a loss of less than $200,000 but greater than $10,000 (average loss of $30,000)*

***Class D Mishap** — a mishap that is categorized as Class D. For the purposes of risk calculations, Class D mishaps are equivalent to a loss of less than $10,000 (average loss of $3,000)*

Using the frequency scoring categories in the figure on the next page, assess the frequency of each deviation occurring and resulting in a (1) Class A/B, (2) Class C, and (3) Class D mishap. Only assess the deviation with respect to the operation/ evolution being considered. Rather than estimating the frequency of each credible deviation's causes occurring and each associated safeguard failing, make higher level, subjective assessments of the overall frequency of each deviation occurring and resulting in mishaps. Each frequency estimate should be based on cumulative frequencies of contributing events.

Tip:
Use available data to develop reasonable frequency estimates
- *MISREP data*
- *CASREP data*
- *Subject matter expert judgment*
- *Generic/vendor data*

IMPORTANT!

Frequency estimates must be assigned by determining the frequency of a mishap occurring at a unit. However, it may be necessary to consider an entire unit class when determining the frequency of a mishap. If this is the case, the frequency score for the unit class must be converted to a score for a single unit. For example, determining the frequency of capsizing the vessel may be difficult to consider for a single vessel because of the small experience base being considered. Experience for the vessel class may indicate that for 10 vessels in the class, 1 vessel has capsized in 15 years (e.g., in 150 years of vessel experience). Thus, the frequency of a single vessel capsizing is 1/150 or once every 150 years.

Frequency Scoring Categories

Frequency Score Descriptions	Frequency Scores (with indicated frequency bounds)	Example Benchmarks for Assigning Categories for a Single Vessel
Continuous Will occur almost continuously (100 or more times per year)	8	
	100/y	
Very Frequent Will occur very frequently (10 to 100 times per year)	7	← One event each week ← One event each month
	10/y	
Frequent Will occur frequently (1 to 10 times per year)	6	← One event each quarter
	1/y	← One event per year
Occasional Will occur periodically (one time every 1 to 10 years)	5	← One event over one tour (3 years)
	0.1/y	← One event over three tours (9 years)
Probable Will occur a few times over a 50-year period (one time every 10 years to 50% chance over a 50-year period)	4	← 10% chance of an event over one tour (3 years) ← 10% chance of an event over three tours (9 years)
	1×10^{-2}/y	
Improbable Unlikely, but reasonably expected to occur (50% to 5% chance over a 50-year period)	3	← 1% chance of an event over one tour (3 years)
	1×10^{-3}/y	← 1% chance of an event over three tours (9 years)
Rare Very unlikely, but credible (5% to 0.5% chance over a 50-year period)	2	← 1-in-1000 chance of an event over one tour (3 years)
	1×10^{-4}/y	← 1-in-1000 chance of an event over three tours (9 years)
Remote Extremely unlikely, but not physically impossible (0.5% to 0.005% chance over a 50-year period)	1	
	1×10^{-5}/y	← ~1-in-10,000 chance of an event over three tours (9 years)
Incredible Physically impossible or virtually impossible (less than 0.005% chance over a 50-year period)	0	← ~1-in-100,000 chance of an event over three tours (9 years)

Step 3.B.2 Calculate the risk index number (RIN)

Coarse Hazard Analysis of WHEC-378										
Operation/evolution: Towing										
Function: Operating vessels/craft										
				Freq.						
No.	Deviation	Causes	Mishaps	A/B	C	D	RIN	Certainty	Safeguards	Recommend-ations
1.1	Incorrect position/ direction/ speed	Mechanical failure of steering system Mechanical failure of main diesel engine Officer of the deck chooses/orders wrong vessel course	Collision with a fixed object Collision with another vessel Grounding vessel	3	4	3	0 0603	High	PQs for bridge watch-standers Preventive maintenance on the engines	Consider performing preventive maintenance on the steering system

***Risk Index Number** — a relative measure of the overall risk associated with a deviation*

Calculate the RIN for each deviation by using the following equation:

$$\mathbf{RIN = (0.3 * 10^{(FsA/B)} + 0.03 * 10^{(FsC)} + 0.003 * 10^{(FsD)})/10{,}000}$$

Where:

FsA/B = the frequency score for Class A/B mishaps
FsC = the frequency score for Class C mishaps
FsD = the frequency score for Class D mishaps

This equation is derived assuming an average Class A/B mishap is equivalent to \$300,000, an average Class C mishap is equivalent to \$30,000, and an average Class D mishap is equivalent to \$3,000. The following page contains the complete derivation.

Derivation of the RIN equation

Frequency and Consequence Table				
Freq. Score	Freq.	Cat.	Cons. Score	Cons.
8 7 6 • • •	100 10 1 • • •	A/B C D	3 2 1	300K 30K 3K

Risk (R) = Frequency (F) * Consequence (C)

$F = 10^{(Fs + Fc)}$

Where:

Fs = Frequency Score *(Coarse Hazard Analysis)*

Fc = Frequency Correction Factor

Fc Derivation

$$\begin{aligned} \text{Frequency} &= 10^{(Fs + Fc)} \\ 100 &= 10^{(8+Fc)} \\ \text{Log}_{10}\,100 &= 8+Fc \\ Fc &= -6 \end{aligned}$$

$C = 10^{(Cs + Cc)}$

Where:

Cs = Consequence Score *(for Class A/B, C, or D mishaps)*

Cc = Consequence Correction Factor

Cc Derivation

$$\begin{aligned} \text{Consequence} &= 10^{(Cs + Cc)} \\ 300K &= 10^{(3+Cc)} \\ \text{Log}_{10}\,300K &= 3+Cc \\ Cc &= 2.477\sim2.5 \end{aligned}$$

$R = 10^{(Fs + Fc)} * 10^{(Cs + Cc)}$

$R = 10^{(Fs - 6 + Cs + 2.5)}$

$R = 10^{(Fs + Cs - 3.5)}$

$\Sigma R = R_{A/B} + R_C + R_D$ *(total risk for a deviation)*

$\Sigma R = 10^{(FsA/B + CsA/B - 3.5)} + 10^{(FsC + CsC - 3.5)} + 10^{(FsD + CsD - 3.5)}$

$\Sigma R = 10^{(FsA/B - 0.5)} + 10^{(FsC - 1.5)} + 10^{(FsD - 2.5)}$

$\Sigma R = 0.3 * 10^{(FsA/B)} + 0.03 * 10^{(FsC)} + 0.003 * 10^{(FsD)}$

$RIN = (0.3 * 10^{(FsA/B)} + 0.03 * 10^{(FsC)} + 0.003 * 10^{(FsD)})/10{,}000$

Step 3.B.3 Characterize the certainty of the frequency estimate

Coarse Hazard Analysis of WHEC-378										
Operation/evolution: Towing										
Function: Operating vessels/craft										
				Freq.						
No.	Deviation	Causes	Mishaps	A/B	C	D	RIN	Certainty	Safeguards	Recommendations
1.1	Incorrect position/ direction/ speed	Mechanical failure of steering system Mechanical failure of main diesel engine Officer of the deck chooses/orders wrong vessel course	Collision with a fixed object Collision with another vessel Grounding vessel	3	4	3	0.0603	High	PQs for bridge watch-standers Preventive maintenance on the engines	Consider performing preventive maintenance on the steering system

***Certainty** — the confidence in the frequency assessments of Class A/B, Class C, and Class D mishaps occurring*

Characterize the confidence in the assessment of the frequency scores for each deviation. This subjective rating helps to qualify the risk estimates. For example, a medium risk deviation with a High certainty may deserve the same or more attention than a high risk deviation with a Low certainty.

Certainty categories:

High — very confident in assigned frequency categories; typically used when (1) there is a strong understanding of mishap mechanisms and/or (2) there have been a significant number of previous occurrences, or there is a large relevant population with few or no occurrences

Medium — comfortable with assigned frequency categories; typically used when (1) there is a moderate understanding of mishap mechanisms and/or (2) there have been only a few (or no) previous occurrences, or there is at least modest relevant population with few (or no) previous occurrences

Low — little confidence in assigned frequency categories; typically used when (1) there is no strong understanding of mishap mechanisms and/or (2) there have been few (or no) previous occurrences and relevant populations are small

Step B.4 Evaluate location risk

Operation/Evolution:	Damage control fire
Function:	*Providing fire services*
Deviation:	Physical hazards exposure

Location	Contribution to Deviation Risk
Machinery spaces	H
Engine room	M
Deck	N
Berthing	L

For each location associated with the deviation (typically, locations are associated with functions and, therefore, all deviations within the function are associated with the location), determine the contribution the location makes to the deviation risk. Contribution is defined in the following table.

Note:
If the locations are screened, meaning that no judgment was made as to the contribution the location makes to the risk associated with the deviation, all of the locations will default to moderate (M).

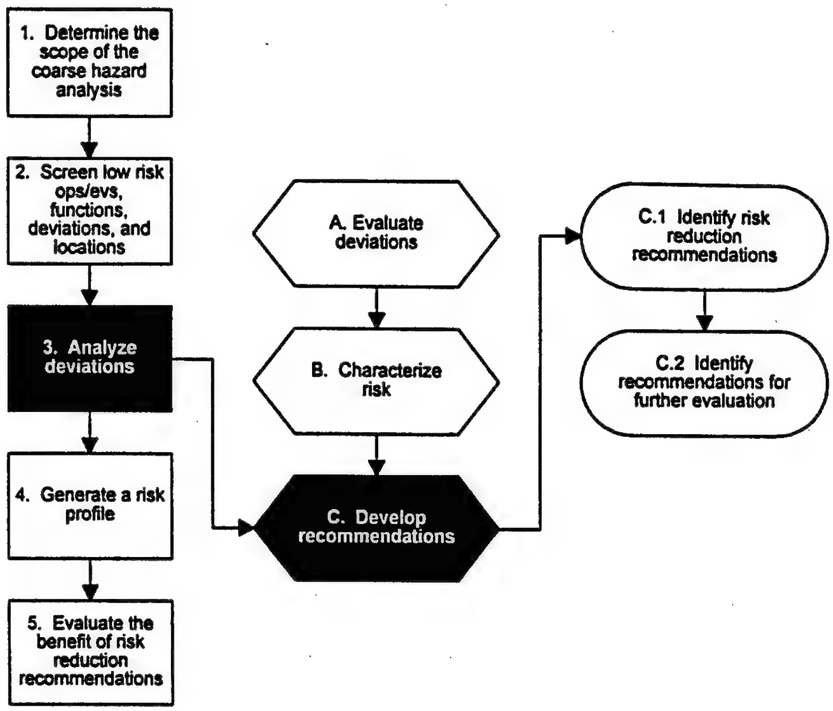
Contribution	Description
H	High contributor to the deviation risk; most all of the deviation risk is due to this location
M	Moderate contributor to the deviation risk; a moderate (significant) portion of the deviation is due to this location
L	Low contributor to the deviation risk; a minimal portion of the deviation risk is due to this location
N	No or little significant contribution to the deviation risk; little or no portion of the deviation risk is due to this location

IMPORTANT!

It is very important to consider both the frequency of the deviation occurring as well as the consequence of the associated mishaps due to the location.

For example:

As shown in the table at the top of this page, when the deviation "physical hazards exposure" occurs, it is expected that activities or equipment in the machinery spaces will most likely cause the deviation, and the consequences will be the same as if the deviation were caused by events in another location. The machinery spaces make a high contribution to the deviation risk.



Step 3.C Develop recommendations

Coarse Hazard Analysis of WHEC-378										
Operation/evolution: Towing										
Function: Operating vessels/craft										
				Freq.						
No.	Deviation	Causes	Mishaps	A/B	C	D	RIN	Certainty	Safeguards	Recommend-ations
1.1	Incorrect position/ direction/ speed	Mechanical failure of steering system Mechanical failure of main diesel engine Officer of the deck chooses/orders wrong vessel course	Collision with a fixed object Collision with another vessel Grounding vessel	3	4	3	0.0603	High	PQs for bridge watch-standers Preventive maintenance on the engines	Consider performing preventive maintenance on the steering system

***Recommendations** — suggestions and action items for (1) reducing the risk associated with a deviation and/or (2) providing more extensive evaluation of specific issues*

Risk reduction recommendations and recommendations suggesting more in-depth review are necessary for high risk deviations or deviations with low levels of certainty.

Steps used to develop recommendations

3.C.1 Identify risk reduction recommendations

3.C.2 Identify recommendations for further evaluation

Step 3.C.1 **Identify risk reduction recommendations**

Risk reduction recommendations should accomplish one or more of the following:

- Eliminate/mitigate hazards
- Prevent deviations
- Ensure that existing safeguards are dependable
- Provide additional safeguards
- Prevent/mitigate mishaps
- Prevent/mitigate the effects of mishaps

Note:
Be certain that risk reduction recommendations:
- *Do not unknowingly increase other risks*
- *Are practical*
- *Effectively focus on pertinent risk issues*

Example:
- Consider providing fixed fire protection for the vessel's engine room and auxiliary room
- Consider providing machine guards for the cable/spool pinch-points on the cross-deck winches

Step 3.C.2 Identify recommendations for further evaluation

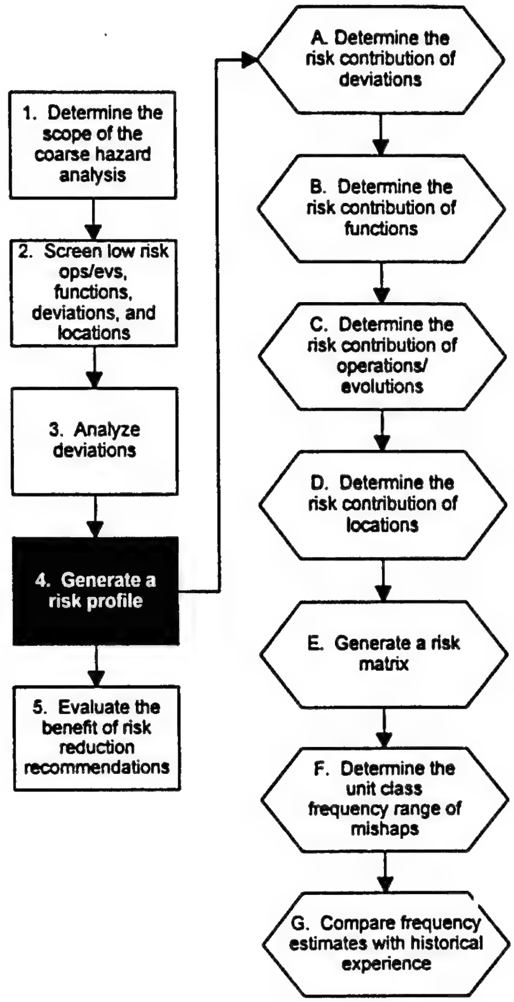
Some deviations or issues may require a more detailed analysis. Such situations include:

- High risk deviations/issues where more resolution is needed to develop risk reduction measures
- Potentially significant deviations/issues with a low level of certainty in the risk assessment or the information gathered about the mishap scenario

Examples:

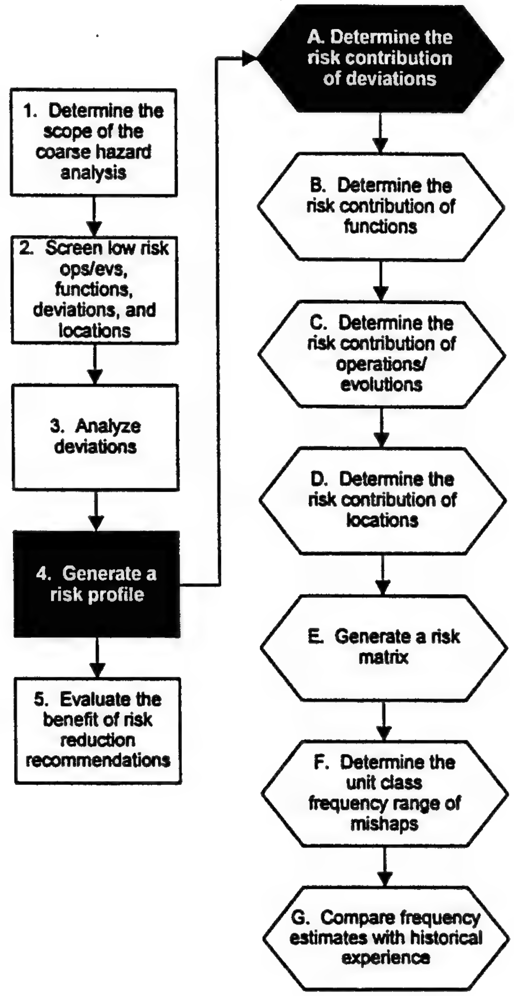
Situation 1 — Consider performing more detailed hazard evaluation of the equipment/procedures used for lifting objects (e.g., piles, buoys, wreckage) to ensure that existing procedures and equipment configurations/preventive maintenance (1) provide adequate protection against dropping loads and (2) are consistent with good engineering practices

Situation 2 — Consider performing a more detailed analysis of the electrical systems aboard the vessel to specifically identify and evaluate (1) the potential for electrical fires and (2) the potential for electrical shocks of crew members



Step 4 Generate a Risk Profile

To effectively manage risk, Coast Guard decision makers must analyze the risk associated with a unit class from several perspectives. The coarse hazard analysis provides risk information for each deviation within a function within an operation/ evolution. Risk associated with each deviation is the basic information required to analyze overall unit class risk.



Step 4.A Determine the risk contribution of deviations

Determining the risk contribution importance (risk contribution) of deviations provides a means to focus resources as narrowly as possible on deviations that are estimated to be the dominant risk contributors for a unit class.

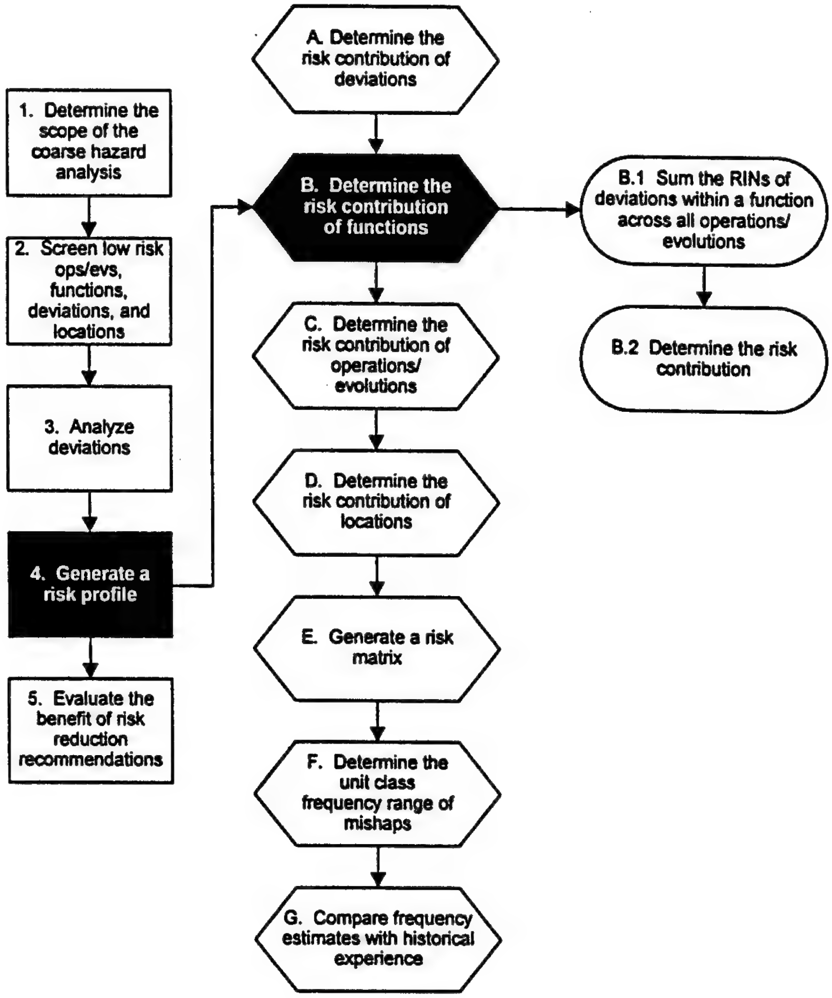
Deviations Ranked by Risk Contribution	
Operation/Evolution *Function* Deviation	**Risk Contribution**
Boarding *Providing assessment/investigation/coordination services* Physical hazards exposure	0.05
Towing *Operating vessels/craft* Incorrect position/direction/speed	0.009
Towing *Operating deck equipment* Hot/cold environment exposure	0.009
Small boat launch/recovery from vessel *Operating lifting equipment* Loss of support	0.007

Use the following equation to determine risk contribution:

Risk contribution = RIN (of the deviation)/Total unit risk (ΣRIN)

Example:

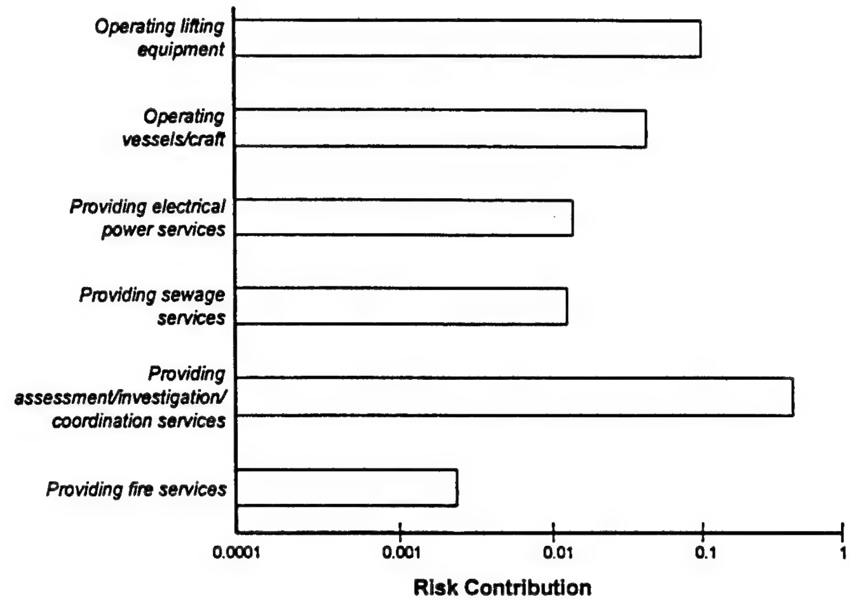
Total vessel risk (ΣRIN) = 633
RIN for "physical hazards exposure" = 33.3
Risk contribution of "physical hazards exposure" = 33.3/633
= 0.053



Step 4.B Determine the risk contribution of functions

Although most risk management resources are targeted as narrowly as possible toward the highest individual risk contributors, some risk management decisions (especially training and research decisions) are frequently based on broader characterizations of risks such as risk associated with a **unit function** (e.g., *operating vessels/craft, providing electrical power services*).

Risk contribution histogram for functions



Steps used to determine the risk contribution of functions

4.B.1 Sum the RINs of deviations within a function across all operations/evolutions

4.B.2 Determine the risk contribution

Step 4.B.1 Sum the RINs of deviations within a function across all operations/evolutions

Function	Operation/Evolution	Deviation	RIN
Operating lifting equipment	Small boat launch/recovery	Loss of support	0.9
		Physical hazards exposure	60
		Hot/cold environment exposure	0.06
	Anchored/moored/stored	Physical hazards exposure	30.003
		Loss of support	0.6
	Not operation/evolution specific	Physical hazards exposure	3.3
	ΣRIN for *operating lifting equipment*		94.863
Operating vessels/craft	Towing	Vessel struck by another vessel	0.006
		Incorrect position/direction/ speed	0.0603
		Physical hazards exposure	0.063
	Vessel leaving or returning	Incorrect position/direction/ speed	0.33
	ΣRIN for *operating vessels/craft*		0.4593

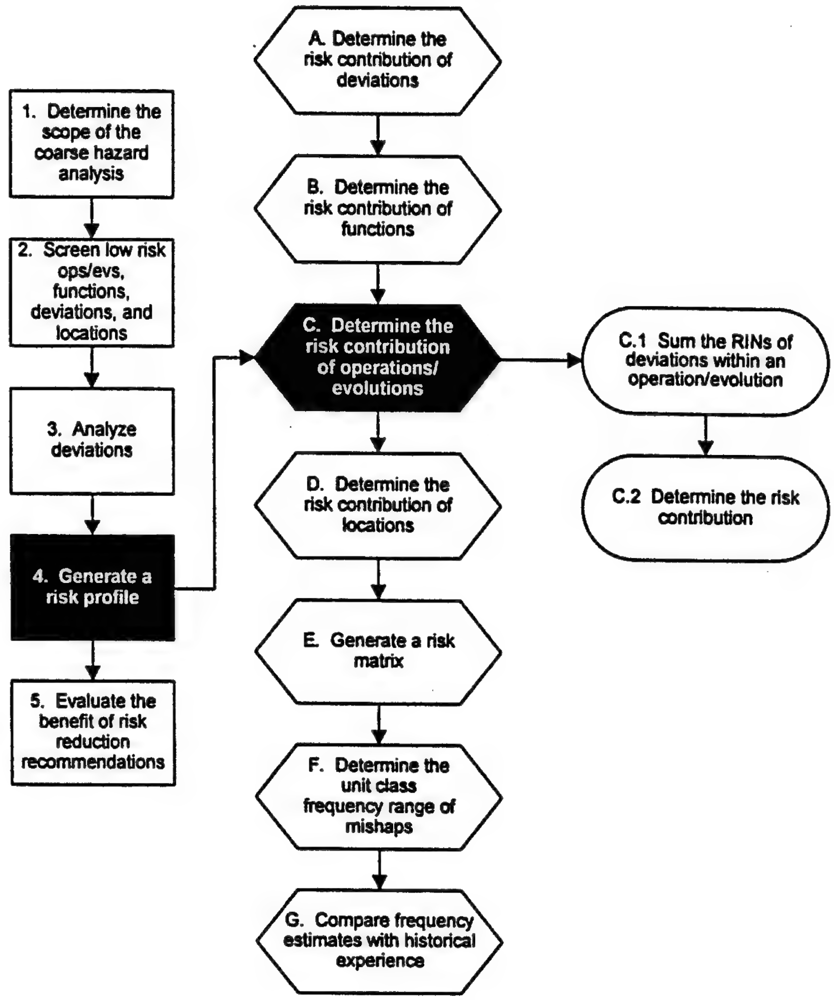
As shown above, include the deviations of the function for each operation/evolution under review.

Step 4.B.2 **Determine the risk contribution**

Divide the total risk for the function calculated in the first step by the total risk for the unit (ΣRIN)

Example:

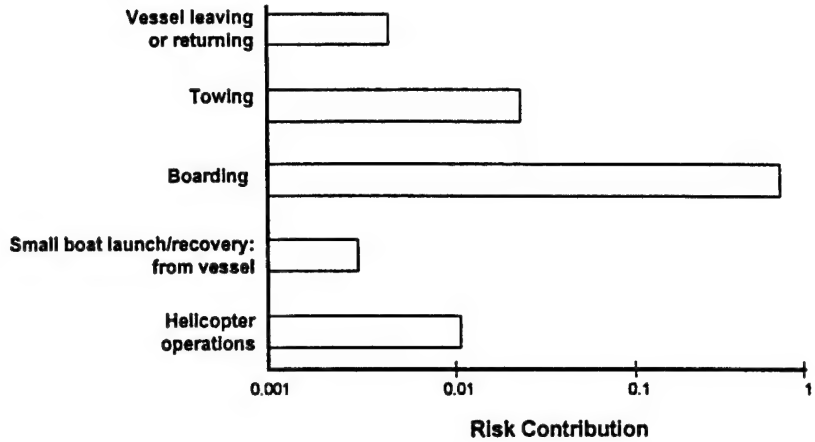
Total vessel risk (ΣRIN)	=	633
RIN for *operating lifting equipment*	=	94.863
Risk contribution of *operating lifting equipment*	=	94.863/633
	=	0.15



Step 4.C Determine the risk contribution of operations/evolutions

Although most risk management resources are targeted as narrowly as possible toward the highest individual risk contributors, some risk management decisions (especially training and research decisions) are frequently based on broader characterizations of risks according to the type of **operation/ evolution** (e.g., **towing, boarding**).

Risk contribution histogram for operations/evolutions



Steps to determine the risk contribution of operations/evolutions

4.C.1 Sum the RINs of deviations within an operation/evolution

4.C.2 Determine the risk contribution

Step 4.C.1 Sum the RINs of deviations within each operation/evolution

Include all deviations within the functions applicable to the operation/evolution.

Operation/Evolution	Function	Deviation	RIN
Helicopter operations	*Operating vessels/craft*	Incorrect position/direction/speed	3.6
		Vessels/craft unavailable	0.3003
		Physical hazards exposure	0.63
	Providing fueling services	Fire/explosion	3.003
	Operating aircraft	Physical hazards exposure	0.63
		High noise exposure	0.06
	ΣRIN for helicopter operations		8.223
Towing	*Operating vessels/craft*	Vessels/craft unavailable	0.006
		Incorrect position/direction/speed	0.0603
		Physical hazards exposure	0.063
	Operating deck equipment	Physical hazards exposure	3.003
		Hot/cold environment exposure	0.006
	ΣRIN for towing		3.138

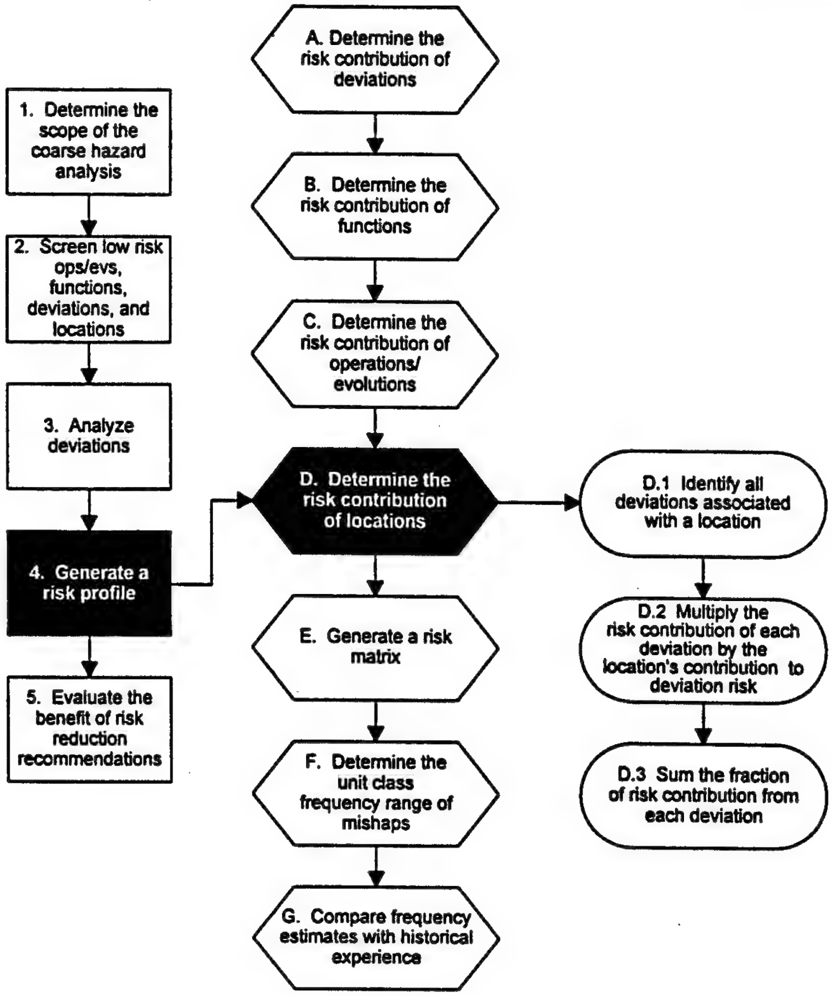
Step 4.C.2 Determine the risk contribution

Divide the total risk for the operation/evolution by the total risk for the unit (ΣRIN)

Example:

Total vessel risk (ΣRIN) = 633
RIN for **helicopter operations** = 8.223

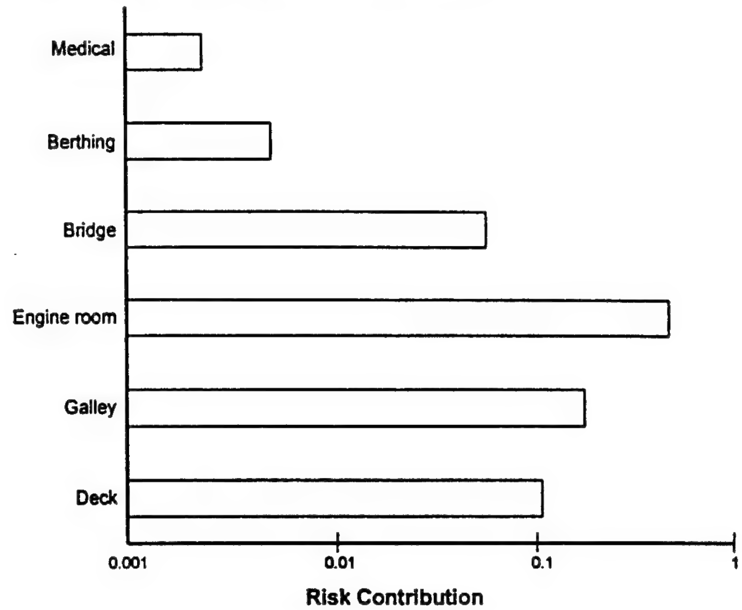
Risk contribution of **helicopter operations** = 8.223/633
= 0.013



Step 4.D Determine the risk contribution of locations

Determining the risk contribution of locations provides a means for the Coast Guard to understand the contribution of each unit location to overall unit risk. A prioritized list of locations will help Coast Guard decision makers determine the locations of the unit on which to focus risk reduction efforts.

Histogram for location risk contribution



Steps used to determine risk contribution of locations

4.D.1 Identify all deviations associated with a location

4.D.2 Multiply the risk contribution of each deviation by the location's contribution to deviation risk

4.D.3 Sum the fraction of risk contribution from each deviation

Step 4.D.1 Identify all deviations associated with the location, the contribution of the location to each deviation risk, and the risk contribution of the deviations

Location	Deviations	Contribution of Location	Deviation Risk Contribution	Location Contribution by Deviation
Machinery spaces	**Not operation/evolution specific** *Operating hand-operated moving equipment* Physical hazards exposure	H	0.0025	
	Not operation/evolution specific *Providing/maintaining structures* Physical hazards exposure	H	0.0105	
	Not operation/evolution specific *Providing/maintaining structures* Toxic/corrosive/reactive materials exposure	H	0.233	
	Not operation/evolution specific *Operating lifting equipment* Physical hazards exposure	L	0.003	
	Not operation/evolution specific *Operating lifting equipment* Loss of support	M	0.0045	
	Risk contribution of machinery spaces			

Step 4.D.2 Multiply the risk contribution of each deviation by the weight of the contribution of the location

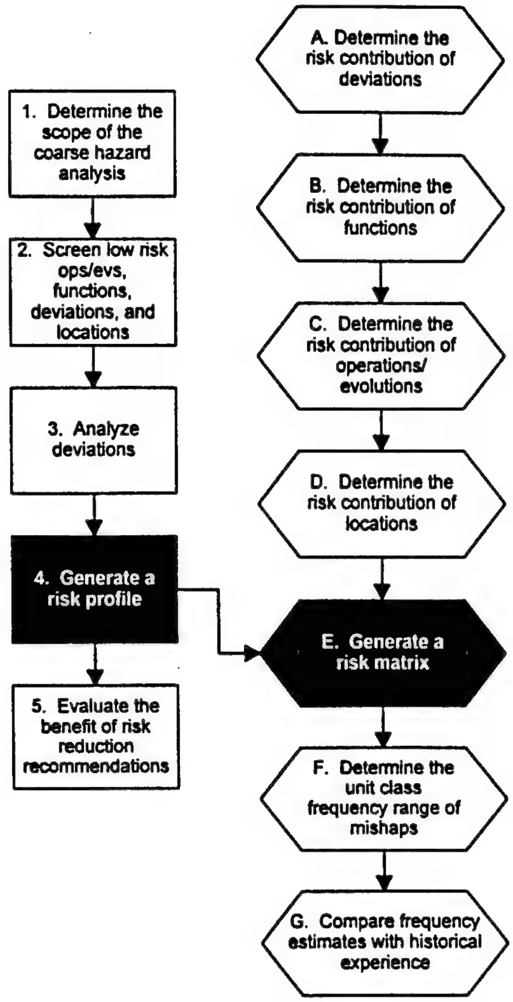
The weight of the contribution is defined as follows:

Contribution	Contribution Weight
H	10
M	1
L	0.1
N	0

Location	Deviations	Contribution of Location	Deviation Risk Contribution	Location Contribution by Deviation
Machinery spaces	**Not operation/evolution specific** *Operating hand-operated moving equipment* Physical hazards exposure	H	0.0025	0.025
	Not operation/evolution specific *Providing/maintaining structures* Physical hazards exposure	H	0.0105	0.105
	Not operation/evolution specific *Providing/maintaining structures* Toxic/corrosive/reactive materials exposure	H	0.233	2.33
	Not operation/evolution specific *Operating lifting equipment* Physical hazards exposure	L	0.003	0.0003
	Not operation/evolution specific *Operating lifting equipment* Loss of support	M	0.0045	0.0045
	Risk contribution of machinery spaces			

Step 4.D.3 Sum the fraction of risk contribution from each deviation

Location	Deviations	Contribution of Location	Deviation Risk Contribution	Location Contribution by Deviation
Machinery spaces	Not operation/evolution specific *Operating hand-operated moving equipment* Physical hazards exposure	H	0.0025	0.025
	Not operation/evolution specific *Providing/maintaining structures* Physical hazards exposure	H	0.0105	0.105
	Not operation/evolution specific *Providing/maintaining structures* Toxic/corrosive/reactive materials exposure	H	0.233	2.33
	Not operation/evolution specific *Operating lifting equipment* Physical hazards exposure	L	0.003	0.0003
	Not operation/evolution specific *Operating lifting equipment* Loss of support	M	0.0045	0.0045
	Risk contribution of machinery spaces			2.5



Step 4.E Generate a risk matrix

Risk matrix *— a matrix depicting the risk profile of a class of unit. Each cell in the matrix indicates the number of deviations having that frequency and consequence*

	A/B	C	D
Continuous (8)	0	0	0
Very frequent (7)	0	2	2
Frequent (6)	0	5	5
Occasional (5)	1	9	9
Probable (4)	2	15	22
Improbable (3)	6	14	14
Rare (2)	11	17	10
Remote (1)	36	20	3
Incredible (0)	9	4	0

Number of Mishaps

The risk matrix illustrates the distribution of deviations according to their frequency of producing Class A/B, Class C, and Class D mishaps. The matrix is a valuable risk communication tool and helps decision makers understand how many deviations fall into the various categories.

Note:
*The risk matrix represents a **typical** unit in a unit class. For a matrix that depicts the total number of mishaps in each frequency category for the entire class, each cell of the risk matrix should be multiplied by the number of units in the unit class.*

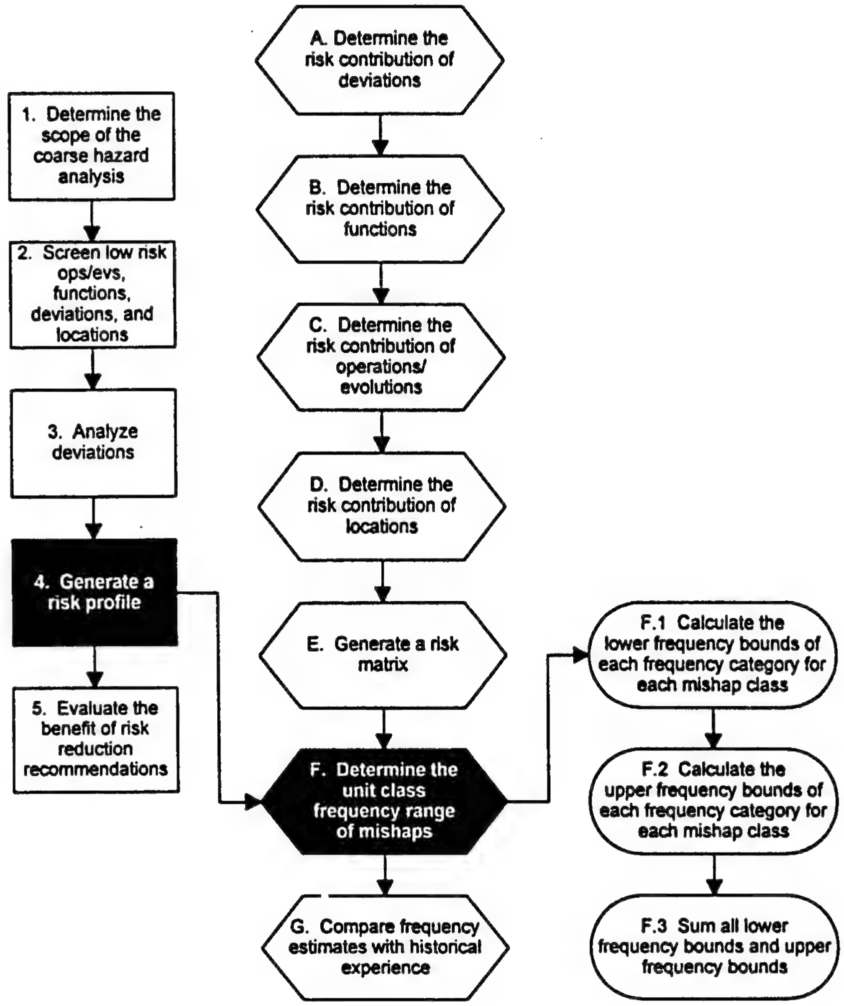
To develop a risk matrix from the coarse hazard analysis, total the number of deviations potentially resulting in a Class A/B, Class C, and Class D mishap for each frequency category.

Deviation	Frequency Scores		
	A/B	C	D
Deviation 1	5	4	7
Deviation 2	2	4	7
Deviation 3	0	3	4
Deviation 4	1	2	6

Example

There are two deviations with a Class C risk score of 4.

	Class A/B Mishap	Class C Mishap	Class D Mishap
Continuous (8)	0	0	0
Very frequent (7)	0	0	2
Frequent (6)	0	0	1
Occasional (5)	1	0	0
Probable (4)	0	2	1
Improbable (3)	0	1	0
Rare (2)	1	1	0
Remote (1)	1	0	0
Incredible (0)	1	0	0



Step 4.F Determine the unit class frequency range of mishaps

***Frequency range** — a lower and upper limit representing the estimated frequency of occurrence of a class of mishap*

The frequency of a Class A/B, Class C, and Class D mishap for a unit class (i.e., cumulative effect of all of the individual deviations) is determined by using the frequency bounds for the frequency categories shown in the risk matrix. The frequency bounds are defined in Step 3.B.

The frequency ranges for Class A/B, Class C, and Class D mishaps are useful in understanding the overall risk associated with a unit class. They also provide a means to validate the frequency estimates in the coarse hazard analysis by comparing the estimates with historical mishap data described in the next section.

Overall frequency bounds for Class A/B, C, and D mishaps

Frequency Category	Frequency Bounds (per year)		Risk Matrix			Estimated Frequency Range for Class A/B Mishaps (per year)		Estimated Frequency Range for Class C Mishaps (per year)		Estimated Frequency Range for Class D Mishaps (per year)	
	Lower	Upper	A/B	C	D	Lower	Upper	Lower	Upper	Lower	Upper
Continuous (8)	100	No limit (100)	0	0	0	0	0	0	0	0	0
Very Frequent (7)	10	100	0	0	2	0	0	0	0	20	200
Frequent (6)	1	10	0	1	5	0	0	1	10	5	50
Occasional (5)	0.1	1	1	2	9	0.1	1	0.2	2	0.9	9
Probable (4)	0.01	0.1	2	14	22	0.02	0.2	0.14	1.4	0.22	2.2
Improbable (3)	0.001	0.01	6	9	14	0.006	0.06	0.009	0.09	0.014	0.14
Rare (2)	0.0001	0.001	11	15	10	0.0011	0.011	0.0015	0.015	0.001	0.01
Remote (1)	0	0.0001	36	20	3	0	0.0036	0	0.002	0	0.0003
Incredible (0)	0	0	9	4	0	0	0	0	0	0	0
Frequency Range						0.1271	1.2746	1.3505	13.507	26.135	261.35

Steps to determine the unit class frequency range of mishaps

4.F.1 Calculate the lower frequency bounds of each frequency category for each mishap class

4.F.2 Calculate the upper frequency bounds of each frequency category for each mishap class

4.F.3 Sum all lower frequency bounds and upper frequency bounds

Step 4.F.1 **Calculate the lower bounds of the estimated frequency range for Class A/B mishaps by multiplying the lower frequency bounds times the number of deviations with Class A/B mishaps in each frequency category**

Frequency Category	Frequency Bounds (per year)		Risk Matrix			Estimated Frequency Range for Class A/B Mishaps (per year)		Estimated Frequency Range for Class C Mishaps (per year)		Estimated Frequency Range for Class D Mishaps (per year)	
	Lower	Upper	A/B	C	D	Lower	Upper	Lower	Upper	Lower	Upper
Continuous (8)	100	No limit (100)	0	0	0	0					
Very Frequent (7)	10	100	0	0	2	0					
Frequent (6)	1	10	0	1	5	0					
Occasional (5)	0.1	1	1	2	9	0.1					
Probable (4)	0.01	0.1	2	14	22	0.02					
Improbable (3)	0.001	0.01	6	9	14	0.006					
Rare (2)	0.0001	0.001	11	15	10	0.0011					
Remote (1)	0	0.0001	36	20	3	0					
Incredible (0)	0	0	9	4	0	0					
Frequency Range											

Step 4.F.2 Calculate the upper bounds of the estimated frequency range for Class A/B mishaps by multiplying the upper frequency bounds times the number of deviations with Class A/B mishaps in each frequency category

Frequency Category	Frequency Bounds (per year)		Risk Matrix			Estimated Frequency Range for Class A/B Mishaps (per year)		Estimated Frequency Range for Class C Mishaps (per year)		Estimated Frequency Range for Class D Mishaps (per year)	
	Lower	Upper	A/B	C	D	Lower	Upper	Lower	Upper	Lower	Upper
Continuous (8)	100	No limit (100)	0	0	0	0	0				
Very Frequent (7)	10	100	0	0	2	0	0				
Frequent (6)	1	10	0	1	5	0	0				
Occasional (5)	0.1	1	1	2	9	0.1	1				
Probable (4)	0.01	0.1	2	14	22	0.02	0.2				
Improbable (3)	0.001	0.01	6	9	14	0.006	0.06				
Rare (2)	0.0001	0.001	11	15	10	0.0011	0.011				
Remote (1)	0	0.0001	36	20	3	0	0.0036				
Incredible (0)	0	0	9	4	0	0	0				
Frequency Range											

Note:
The upper frequency bounds for the frequency category "Continuous (8)" is "No Limit." For this calculation, use 100 as the limit.

Step 4.F.3 Total the lower and upper bounds columns for the overall frequency bounds of Class A/B mishaps (repeat steps for all classes of mishaps)

Frequency Category	Frequency Bounds (per year)		Risk Matrix			Estimated Frequency Range for Class A/B Mishaps (per year)		Estimated Frequency Range for Class C Mishaps (per year)		Estimated Frequency Range for Class D Mishaps (per year)	
	Lower	Upper	A/B	C	D	Lower	Upper	Lower	Upper	Lower	Upper
Continuous (8)	100	No limit (100)	0	0	0	0	0				
Very Frequent (7)	10	100	0	0	2	0	0				
Frequent (6)	1	10	0	1	5	0	0				
Occasional (5)	0.1	1	1	2	9	0.1	1				
Probable (4)	0.01	0.1	2	14	22	0.02	0.2				
Improbable (3)	0.001	0.01	6	9	14	0.006	0.06				
Rare (2)	0.0001	0.001	11	15	10	0.0011	0.011				
Remote (1)	0	0.0001	36	20	3	0	0.0036				
Incredible (0)	0	0	9	4	0	0	0				
Frequency Range						0.1271	1.2746				

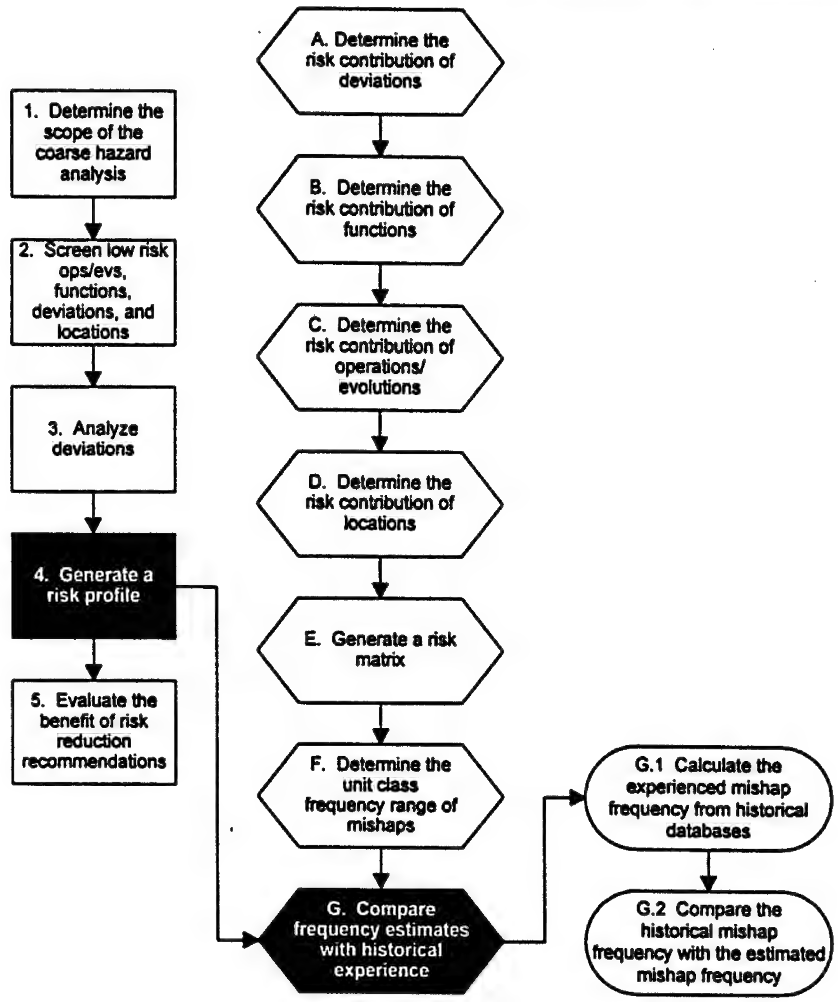
The data from the analysis can be summarized in the table below.

Unit Class	Typical Unit Frequency Range for Mishaps (per year)			Typical Unit Expected Number of Occurrences over 50 Years			Unit Class* Frequency Range for Mishaps (per year)		
	A/B	C	D	A/B	C	D	A/B	C	D
Unit Class 1	0.13 to 1.3	1.4 to 14	26 to 261	7 to 65	70 to 700	1300 or more	1.3 to 13	14 to 140	261 to 2610

*Ten vessels in the example class.

Expected number of occurrences over 50 years is determined by multiplying the frequency range for mishaps (per year) by 50. This information is useful in understanding the expected number of mishaps over the life of a unit class. This can be calculated for any length of time of interest.

Unit class frequency range for mishaps is determined by multiplying the typical unit frequency range by the number of units in the unit class. This information can be used to compare the level of risk associated with different unit classes.



Step 4.G Compare frequency estimates with historical experience

Analyzing historical data provides a means to validate the coarse hazard analysis study.

Unit Class	Unit Class Estimated Frequency Range for Mishaps (per year)			Unit Class Mishap Frequencies Based on Coast Guard (MISREP and CASREP) Data (per year)		
	A/B	C	D	A/B	C	D
Unit Class 1	0.13 to 1.3	1.4 to 14	26 to 261	0.1	5	109

Historical data that are slightly higher than the estimated frequencies from the coarse hazard analysis may reflect:

- A lack of relevant experience among coarse hazard analysis team members with deviations that occur infrequently (e.g., potential omissions in the list of deviations or in the list of causes)
- Implementation of corrective actions to prevent repeated mishaps, reducing the frequency of future events

- A limited number of functions may have been reviewed during the coarse hazard analysis

Historical data that are slightly lower than the estimated frequencies from the coarse hazard analysis may reflect:

- Potential overlap in issues covered by the identified deviations
- Overemphasis by the coarse hazard analysis team on certain events that occurred in recent years

Steps to compare frequency estimates with historical experience

4.G.1 Calculate the experienced mishap frequency from historical databases

4.G.2 Compare the historical mishap frequency with the estimated mishap frequency

Step 4.G.1 **Calculate the experienced mishap frequency for Class A/B, Class C, and Class D mishaps from historical databases**

Frequency for a mishap class = (Number of events in the severity class)/(Time Period)

Note:
Be certain that the complete set of historical data is accounted for when making this comparison. Coast Guard mishap data are currently stored in several databases (i.e., MISREP and CASREP). Also, be certain that mishaps are not double counted when compiling data from these databases.

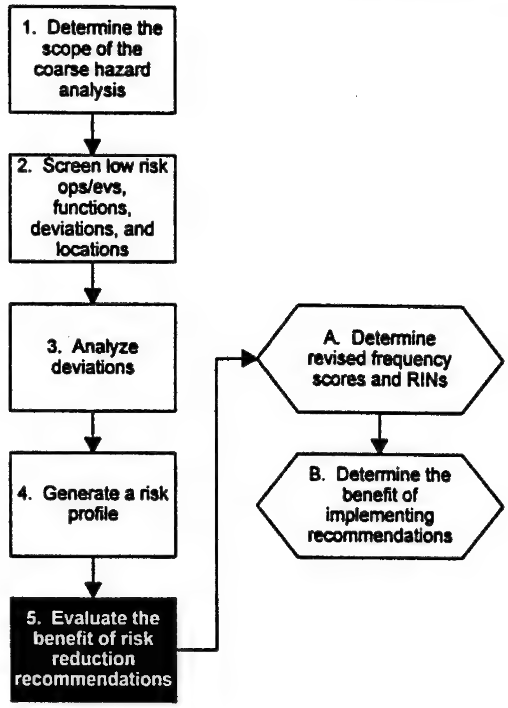
Example:
Class A/B mishaps over a 10-year period = 1

Frequency of
Class A/B mishaps = 1/10

= 0.1 Class A/B mishaps per year for the unit class

Step 4.G.2 Compare the historical mishap frequency with the estimated mishap frequency

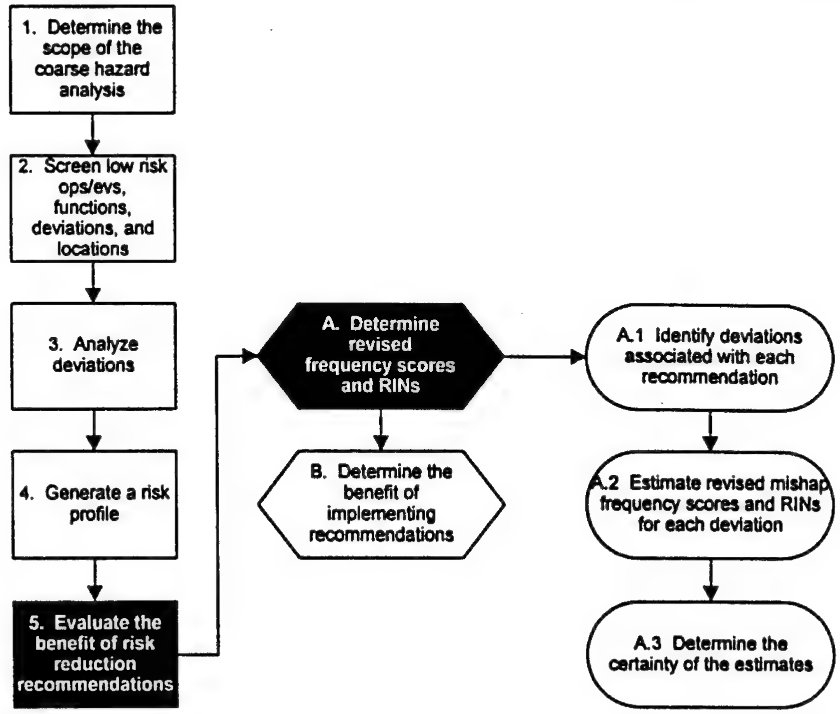
	Unit Class Estimated Frequency Range for Mishaps (per year)			Unit Class Mishap Frequencies Based on Coast Guard (MISREP and CASREP) Data (per year)		
Unit Class	A/B	C	D	A/B	C	D
Unit Class 1	0.13 to 1.3	1.4 to 14	26 to 261	0.1	5	109



Step 5 Evaluate the Benefit of Risk Reduction Recommendations

Each recommendation from the coarse hazard analysis is designed to reduce the risk associated with the deviations discussed during the analysis. These recommendations may serve as preventive or mitigative safeguards, and may apply to more than one deviation.

This section provides a means to estimate the dollar/year savings due to the reduced risk realized by implementing recommendations. The dollar savings can be compared to the implementation cost of the recommendation in a cost/benefit analysis. Decision makers will use this cost/benefit analysis to decide if a recommendation should be implemented.



Step 5.A Determine revised frequency scores and RINs

The benefit of implementing each coarse hazard analysis recommendation is estimated by determining the potential reduction in frequency scores of deviations affected by the recommendations.

Coarse Hazard Analysis Recommendations	Associated Deviations	Initial Frequencies and RIN	Revised Frequencies and RIN	Certainty in Revised RIN	Notes
Recommendation 1- Consider improving the ability of bridge and deck watchstanders to view towing operations and towed vessels by relocating the CIWS	Towing *Operating vessels/ craft* Incorrect position/ direction/speed	2, 3, 4 0.009	1, 2, 3 0.0009	Med	
	Towing *Operating vessels/ craft* Physical hazards exposure	2, 4, 5 0.063	2, 4, 5 0.063	High	No significant risk reduction expected
Recommendation 2- Consider improving the towing gear to increase deck crew efficiency and reduce their exposure to physical hazards	Towing *Operating deck equipment* Physical hazards	1, 3, 7 3.003	2, 3, 4 0.009	Low	

Steps to determine revised frequency scores and RINs

5.A.1 Identify deviations associated with each recommendation

5.A.2 Estimate revised mishap frequency scores and RINs for each deviation

5.A.3 Determine the certainty of the estimates

Step 5.A.1 Identify the deviations associated with each recommendation and their frequency scores and RINs

Coarse Hazard Analysis Recommendations	Associated Deviations	Initial Frequencies and RIN	Revised Frequencies and RIN	Certainty in Revised RIN	Notes
Recommendation 1- Consider improving the ability of bridge and deck watchstanders to view towing operations and towed vessels by relocating the CIWS	Towing *Operating vessels/ craft* Incorrect position/ direction/speed	2, 3, 4 0.009			
	Towing *Operating vessels/ craft* Physical hazards exposure	2, 4, 5 0.063			
Recommendation 2- Consider improving the towing gear to increase deck crew efficiency and reduce their exposure to physical hazards	Towing *Operating deck equipment* Physical hazards	1, 3, 7 3.003			

Step 5.A.2 Estimate revised Class A/B, Class C, and Class D frequency scores for each deviation affected by the recommendation and calculate revised RINs

Coarse Hazard Analysis Recommendations	Associated Deviations	Initial Frequencies and RIN	Revised Frequencies and RIN	Certainty in Revised RIN	Notes
Recommendation 1- Consider improving the ability of bridge and deck watchstanders to view towing operations and towed vessels by relocating the CIWS	Towing *Operating vessels/ craft* Incorrect position/ direction/speed	2, 3, 4 0.009	1, 2, 3 0 0009		
	Towing *Operating vessels/ craft* Physical hazards exposure	2, 4, 5 0.063	2, 4, 5 0.063		
Recommendation 2- Consider improving the towing gear to increase deck crew efficiency and reduce their exposure to physical hazards	Towing *Operating deck equipment* Physical hazards	1, 3, 7 3.003	2, 3, 4 0.009		

Note:
Assume that the recommendation is effectively implemented.

For each deviation, estimate new frequency scores with the recommendation (new safeguard) in place. It may be necessary to review the coarse hazard analysis tables to understand the causes, mishaps, and safeguards associated with the deviation. Calculate a revised RIN using the new frequency scores.

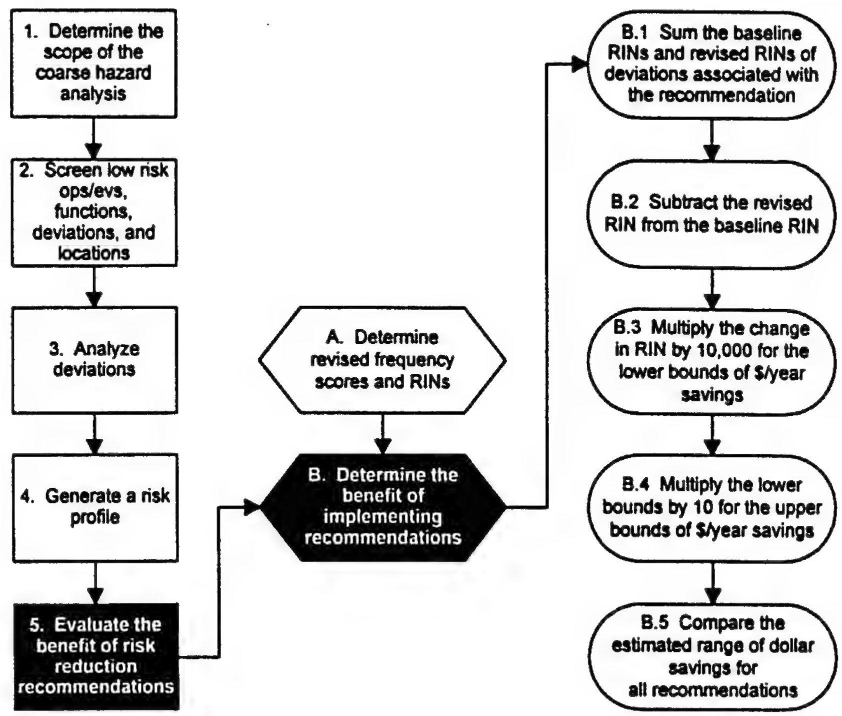
Tip:
$RIN = (0.3 * 10^{(FsA/B)} + 0.03 * 10^{(FsC)} + 0.003 * 10^{(FsD)})/10,000$

Step 5.A.3 Determine the certainty in the estimate of the revised frequency scores and provide any pertinent notes

Coarse Hazard Analysis Recommendations	Associated Deviations	Initial Frequencies and RIN	Revised Frequencies and RIN	Certainty in Revised RIN	Notes
Recommendation 1- Consider improving the ability of bridge and deck watchstanders to view towing operations and towed vessels by relocating the CIWS	Towing *Operating vessels/ craft* Incorrect position/ direction/speed	2, 3, 4 0.009	1, 2, 3 0.0009	Med	
	Towing *Operating vessels/ craft* Physical hazards exposure	2, 4, 5 0.063	2, 4, 5 0.063	High	No significant risk reduction expected
Recommendation 2- Consider improving the towing gear to increase deck crew efficiency and reduce their exposure to physical hazards	Towing *Operating deck equipment* Physical hazards	1, 3, 7 3.003	2, 3, 4 0.009	Low	

Note:
Decision makers will have to consider whether frequencies in the Low certainty category should be used when determining the dollar benefit of the reduced risk.

The certainty characterizes the confidence in the assessment of the frequency scores. The certainty categories are High, Medium, and Low, and are explained in Step 3.B.



Step 5.B Determine the benefit of implementing recommendations

The potential benefit gained from implementing a recommendation can be calculated by determining the change in the risk index numbers for the deviations affected by the recommendations.

Recommendation	Deviation	Baseline RIN	Revised RIN	Change in RIN	Risk Reduction ($/year)	
					Lower	Upper
1	1	0.006	0.0006			
	2	0.09	0.0063			
	3	-	-			
	4	0.36	0.36			
	Total	0.456	0.3669	0.089	890	8,900
2	1	0.36	0.009			
	2	0.36	0.0063			
	3	-	-			
	Total	0.72	0.0153	0.70	7,000	70,000

Steps to determine the benefit of implementing recommendations

5.B.1 Sum the baseline RINs and revised RINs of deviations associated with the recommendation

5.B.2 Subtract the revised RIN from the baseline RIN

5.B.3 Multiply the change in RIN by 10,000 for the lower bounds of $/year savings

5.B.4 Multiply the lower bounds by 10 for the upper bounds of $/year savings

5.B.5 Compare the estimated range of dollar savings for all recommendations

Step 5.B.1 Sum the baseline RINs and revised RINs of deviations associated with the recommendation

Recommendation	Deviation	Baseline RIN	Revised RIN	Change in RIN	Risk Reduction ($/year)	
					Lower	Upper
1	1	0.006	0.0006			
	2	0.09	0.0063			
	3	-	-			
	4	0.36	0.36			
	Total	0.456	0.3669			
2	1	0.36	0.009			
	2	0.36	0.0063			
	3	-	-			
	Total	0.72	0.0153			

Note:
Decision makers will have to consider whether deviations with RIN in the low certainty category should be used when determining the dollar benefit of the reduced risk

Step 5.B.2 Subtract the revised RIN from the baseline RIN to determine the change in RIN

Recommendation	Deviation	Baseline RIN	Revised RIN	Change in RIN	Risk Reduction ($/year)	
					Lower	Upper
1	1	0.006	0.0006			
	2	0.09	0.0063			
	3	-	-			
	4	0.36	0.36			
	Total	0.456	0.3669	0.089		
2	1	0.36	0.009			
	2	0.36	0.0063			
	3	-	-			
	Total	0.72	0.0153	0.70		

Step 5.B.3 Multiply the change in RIN by 10,000 for the lower bounds of $/year savings from the risk reduction

Recommendation	Deviation	Baseline RIN	Revised RIN	Change in RIN	Risk Reduction ($/year)	
					Lower	Upper
1	1	0.006	0.0006			
	2	0.09	0.0063			
	3	-	-			
	4	0.36	0.36			
	Total	0.456	0.3669	0.089	890	
2	1	0.36	0.009			
	2	0.36	0.0063			
	3	-	-			
	Total	0.72	0.0153	0.70	7,000	

The equation for calculating RIN is the risk equation divided by 10,000, and is derived using the lower limits of the frequency categories. Multiplying the RIN by 10,000 results in risk values stated in terms of potential dollar savings on a **yearly** basis. This value is the lower bounds of the estimated savings since it is based on the lower bounds of the frequency categories.

Step 5.B.4 **Multiply the lower bounds by 10 for the upper bounds of $/year savings from the reduced risk**

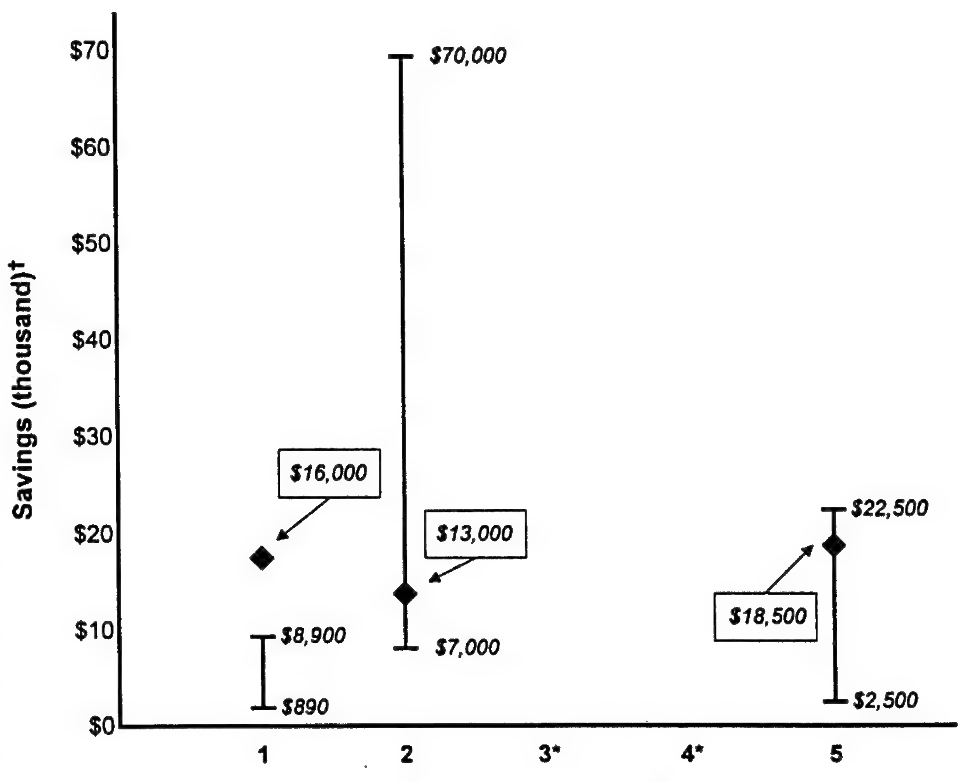
Recommendation	Deviation	Baseline RIN	Revised RIN	Change in RIN	Risk Reduction ($/year)	
					Lower	Upper
1	1	0.006	0.0006			
	2	0.09	0.0063			
	3	-	-			
	4	0.36	0.36			
	Total	0.456	0.3669	0.089	890	8,900
2	1	0.36	0.009			
	2	0.36	0.0063			
	3	-	-			
	Total	0.72	0.0153	0.70	7,000	70,000

The frequency categories represent ranges, and these ranges cover an order of magnitude. Since the RIN equation is derived from the lower frequency bounds, the upper bounds of estimated risk reduction are determined by multiplying the lower bounds by 10. The upper bounds are the maximum estimated $/year savings potentially realized from implementing the recommendation.

Step 5.B.5 Compare the estimated range of dollar savings for all recommendations

The estimated range of dollar savings of each recommendation can be compared in several ways (see graph below). The comparison allows decision makers to decide which recommendation should be implemented and in what order. In the graph, savings is represented over a 50-year period (expected life of a new vessel) by multiplying the savings calculated in the step above by 50. For a unit currently in operation, an appropriate period of time should be chosen. The cost of implementing the recommendation (out of the scope of the IRA process) can be included, as below, to assist decision makers in deciding whether to proceed with implementation or not.

Displaying all recommendations together allows comparison of recommendations so that resources can be spent on the most effective recommendations first.



* A reasonable estimate of savings is only possible after further review.

† Savings estimate assumes Class A/B mishaps cost $300,000 and Class C/D mishaps cost $30,000.

◆ Estimated total cost of implementing recommendation.

Note: Savings shown account for 50-year life of a vessel.

The IRA Coarse Hazard Analysis

- Introduction
- Performing a coarse hazard analysis
- Updating a coarse hazard analysis
- Information exchange between the coarse hazard analysis and the risk-based safety survey
- Making decisions using the coarse hazard analysis
- Evaluating change using a coarse hazard analysis

Updating a Coarse Hazard Analysis

The coarse hazard analysis information will occasionally need to be updated to ensure that an accurate assessment of risk is maintained for each unit class. Potential reasons to update the information include:

- Addition, deletion, or modification of significant unit equipment or systems
- Addition, deletion, or modification of significant administrative processes or procedures
- Significant reduction or addition of manpower for critical operations
- Introduction of new hazards not previously assessed
- An increase in mishaps or near misses

There are two methods to update the coarse hazard analysis information:

1. **Updating the information using the coarse hazard analysis process**

   The simplest way to update the information in the coarse hazard analysis is to re-analyze the section or sections of the analysis requiring the update. This is accomplished by repeating the steps described in performing the coarse hazard analysis.

2. **Updating the information using the IRA safety survey process**

   The coarse hazard analysis information can be updated using historical data from the safety survey process. This method is discussed in the risk-based safety survey section of the manual.

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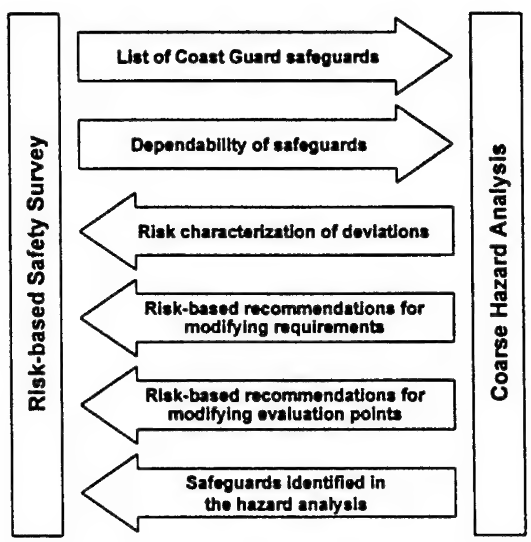
Information Exchange Between the Coarse Hazard Analysis and the Risk-based Safety Survey



Coarse Hazard Analysis ⇨ Risk-based Safety Survey

1. *Risk characterization for deviations*

   The safety survey process uses the risk characterization of deviations to characterize survey findings. By trending findings, the dependability of safeguards can be analyzed. It may be necessary to adjust the risk scores associated with certain deviations to reflect the historical safeguard information from the safety surveys.

2. *Risk-based recommendations for adding/modifying/deleting requirements or evaluation points*

   While evaluating possible deviations that may lead to mishaps, coarse hazard analysis teams may identify that a Coast Guard requirement should be (1) added to provide an additional safeguard or to make an existing safeguard more effective, (2) modified to make an existing safeguard more effective or its implementation less burdensome, and/or (3) eliminated because of marginal (or no) benefit.

3. *Required safeguards identified during the coarse hazard analysis*

   The coarse hazard analysis identifies safeguards necessary to achieve an acceptable level of risk. Requirements and evaluation points ensure these safeguards are effectively performing their design intent.

Risk-based Safety Survey ⇨ Coarse Hazard Analysis

1. *List of Coast Guard safeguards*

   The requirements within the safety surveys define how the Coast Guard will implement safeguards to prevent mishaps. These requirements and safeguards provide the bases for coarse hazard analysis teams to judge whether the risk of possible deviations is acceptable.

2. *Information about the dependability of safeguards*

   Summaries of frequencies/severities of nonconformances from Coast Guard requirements during past surveys help hazard analysis teams judge the dependability of safeguards in preventing mishaps.

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Making Decisions Using the Coarse Hazard Analysis

The IRA hazard analysis results allow decision makers to incorporate risk-based information into the Coast Guard decision-making process. This section describes the ways the Coast Guard decision makers —

- Procurement managers
- Engineering managers
- Facilities managers
- Unit commands
- Unit safety managers
- Senior management

use the hazard analysis results in the following Coast Guard activities:

- Procurement
- Construction, fabrication, and commissioning
- Unit operations and maintenance
- Area, district, or group management of operations and maintenance
- Decommissioning

For each activity, the following table provides typical uses of the hazard analysis that support the activity, example outcomes from using the hazard analysis, and the applicable hazard analysis results required to achieve the outcome. Only the activities that are applicable to a specific decision maker are listed.

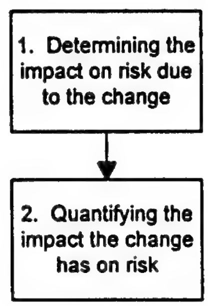
Type of Activity	Decision Maker	Use of Hazard Analysis	Example Outcomes	Applicable Hazard Analysis Results
Procurement	Procurement Managers Engineering Managers Facilities Managers Vessel Safety Managers Senior Management	Identification of major hazards (including human factors issues) and required hazard controls while developing bid specifications for major acquisitions (e.g., new vessels or major onboard systems)	Requiring built-in redundancy for specific components of a vessel's automated navigation system	1. Hazards and required safeguards 2. Recommendations for reducing risk
		Risk-based selection (including consideration of other factors, such as cost) among competing design alternatives for major acquisitions	Determining (and documenting) that Design A provides "best value" to the Coast Guard because it poses significantly less risk of major losses than Design B, which is slightly less expensive	1. Hazards and required safeguards 2. Risk impact of alternatives 3. Risk ranking of design alternatives
Construction, Fabrication, and Commissioning	Engineering Managers Facilities Managers Vessel Safety Managers	Identification of design weaknesses, safe operating limits, critical preventive maintenance tasks, human factors issues, etc., for selected systems (i.e., those that could lead to losses of interest) after the final design is complete for major acquisitions	1. Requiring an audible alarm and semiannual calibration of fathometers for a vessel 2. Requiring the use of a chain fall to lower and raise the safety nets around the flight deck of WHEC-378s	1. Hazards and required safeguards 2. Recommendations for risk reduction
		Evaluation of proposed changes and identified nonconformances from the approved design	Approving a proposed field change (or a recognized nonconformance) in the routing of a high-pressure steam line because the new routing poses no identifiable increase in risks to personnel or equipment	1. Hazards and required safeguards 2. Changes in risk due to design modifications
Vessel Operations and Maintenance	Engineering Managers Facilities Managers Vessel Commands Vessel Safety Managers	Identification of precautions to be taken in performing operations outside of prescribed limits (case-by-case basis for decisions made by vessel-board personnel)	Establishing more stringent maneuvering restrictions and additional watch requirements for performing a search and rescue (SAR) operation in extreme weather conditions that would normally cause discontinuation of the operation	1. Hazards due to abnormal conditions 2. Changes in risk due to the abnormal conditions 3. Additional safeguards for abnormal conditions
		Identification of precautions to be taken in preparation for performing operations when relevant vessel systems will be unavailable (case-by-case basis for operations/ efficiencies identified by vessel-board personnel)	1. Additional precautions when an interlock on an elevator door is out of service 2. Posting additional watches and conducting special operations briefings before conducting an operation	1. Hazards during abnormal conditions 2. Changes in risk due to the abnormal conditions 3. Additional safeguards for abnormal conditions
		Evaluation of proposed changes and identified nonconformances from the standard vessel configuration (case-by-case basis for changes suggested and approved by vessel-board personnel)	Rejecting a request to temporarily store equipment on the deck while a storage locker is being replaced because the movement of the equipment under expected high seas could lead to losses of interest	1. Hazards due to modified vessel configurations 2. Changes in risk due to modified vessel configurations
		Identification of weaknesses in procedures that could lead to losses of interest (case-by-case basis for procedures developed and approved by vessel-board personnel)	Revising vague steps of a procedure (e.g., "open the valve slightly"), because a human error associated with the operation could lead to a loss of interest	1. Hazards and required safeguards 2. Recommendations for risk reduction

Type of Activity	Decision Maker	Use of Hazard Analysis	Example Outcomes	Applicable Hazard Analysis Results
Area, District, or Group Management of Operations and Maintenance	Engineering Managers Facilities Managers Vessel Safety Managers Senior Management	Identification of design weaknesses, safe operating limits, critical preventive maintenance tasks, human factors issues, etc., for selected systems (i.e., those that could lead to losses of interest) aboard existing ships that did not receive such reviews before being placed in operation	1. Recommendations for side-scanning sonar to detect submerged objects for cutters traveling around reefs 2. Recommending redesign of a small craft launching system component that could inadvertently trigger a release of a boat	1. Hazards, required safeguards, and recommendations 2. Vessel risk
		Identification of design weaknesses, safe operating limits, critical preventive maintenance tasks, human factors issues, etc., for selected systems (i.e., those that could lead to losses of interest) aboard existing ships that did not receive such reviews before being placed in operation	1. Recommendations for side-scanning sonar to detect submerged objects for cutters traveling around reefs 2. Recommending redesign of a small craft launching system component that could inadvertently trigger a release of a boat	1. Hazards, required safeguards, and recommendations 2. Vessel risk
		Identification of safe operating limits (from an operations/ command perspective rather than a hardware system design perspective, which was addressed during design reviews) and preferred precautions to be taken if operating outside of such restrictions	Prohibiting aircraft fueling operations and other flammable material handling activities until disabled onboard firefighting systems are returned to service, but allowing emergency fueling operations if another onboard pump can be rigged to temporarily provide adequate firefighting capability	1. Hazards and required safeguards 2. Recommendations for reducing risk 3. Changes in risk when operating out of the restrictions
		Identification of critical training topics, standard procedures necessary, etc., for preventing losses of interest	Deciding to write a special procedure and conduct special training for the proper way to launch a new type of small craft (because the operation is significantly different from similar operations with older small craft)	Hazards, required safeguards, and recommendations
		Identification of weaknesses in procedures and human factors issues that could lead to losses of interest (for standard procedures applicable to a class of vessels or the entire fleet)	Making the units of pressure referenced in a procedure (e.g., SI units) consistent with those commonly used aboard a vessel and on the vessel's gauges (e.g., English units) to help prevent confusion that could lead to an operating error	Hazards, required safeguards, and recommendations
		Evaluation of proposed changes for standard vessel configurations (case-by-case basis for changes approved by group/fleet officers)	Deciding (1) against a crew reduction aboard an MEC 270 cutter because of unacceptable risks associated with degraded watch standards or (2) in favor of a crew reduction provided that each vessel is equipped with new navigation and vessel detection systems	Changes in risk due to modified vessel configurations

Type of Activity	Decision Maker	Use of Hazard Analysis	Example Outcomes	Applicable Hazard Analysis Results
Area, District, or Group Management of Operations and Maintenance (continued)	**Engineering Managers** **Facilities Managers** **Vessel Safety Managers** **Senior Management**	Monitoring profiles of risks for classes of vessels across the Coast Guard to help understand/ manage risks at a fleet level	Determining that a specific class of vessel is the next to receive a major overhaul (or replacement) program because of high loss rates	Risk profiles for vessel classes
		Assigning measures of importance to safety inspection items to help prioritize responses to noted deficiencies	Deferring resolution of a few deficiencies noted during a safety inspection until next fiscal year because the deficiencies do not pose any significant risks of losses	Hazards and required safeguards
		Risk-based selection (including consideration of other factors, such as cost) among competing alternatives such as vessel deployment, mission assignments, etc.	Deciding to send Vessel A on an extended international tour because the potential for losses associated with (1) its tour and (2) its absence from its normal station are less than those for Vessel B	1. Risk ranking of vessel class operations/evolutions and functions 2. Risk profiles for vessel classes
Decommissioning	**Facilities Managers** **Senior Management**	Risk-based selection (including consideration of other factors, such as cost and political pressure) among competing alternatives for vessel/station decommissioning	Deciding (and gaining support for the decision) to decommission Vessel B instead of Vessel A, even though there is some political support for keeping Vessel B in service	Risk profiles of vessels
		Identification of weaknesses in equipment used for decommissioning and associated procedures that could lead to losses of interest	Modifying the equipment and procedures used to de-inventory hazardous materials from a vessel while the vessel is being decommissioned	1. Hazards and required safeguards 2. Recommendations for reducing risk

The IRA Coarse Hazard Analysis

- Introduction
- Performing a coarse hazard analysis
- Updating a coarse hazard analysis
- Information exchange between the coarse hazard analysis and the risk-based safety survey
- Making decisions using the coarse hazard analysis
- Evaluating change using a coarse hazard analysis

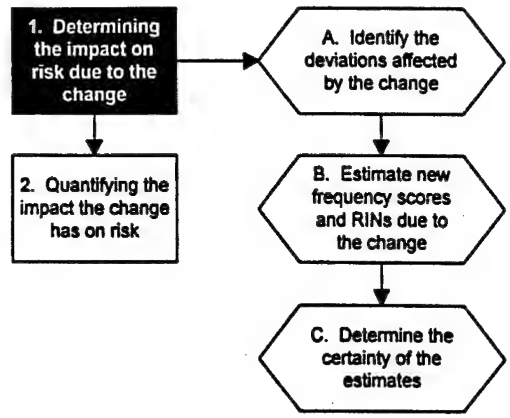


Evaluating Change Using a Coarse Hazard Analysis

An important use of the hazard analysis is to evaluate how change affects risk. Change includes:

- Addition, deletion, or modification of equipment or systems
- Addition, deletion, or modification of administrative processes or procedures
- Addition or reduction of manpower
- Introduction of new processes, operations, materials, etc.

Understanding how change affects risk is critical when making decisions concerning the change. This section discusses how to evaluate change using the coarse hazard analysis.



Step 1 Determine the Impact on Risk Due to the Change

Determining the impact on risk due to a change is accomplished by determining the potential increase or decrease in frequency scores of the deviations affected by the change.

Note:
At the conclusion of this analysis (determining the impact on risk due to a change), it may be necessary to recommend ways to reduce risk caused by implementing the change.

Change	Associated Deviation(s)	Initial Frequencies and RIN	Revised Frequencies and RIN Due to the Change	Certainty in Revised RIN	Notes
1. Replacement of the brake and winch on the MSB lifting/ lowering system with a winch capable of payin and payout	**Small boat launch/recovery** *Operating lifting equipment* Incorrect load position/ direction/speed	3, 3, 4 0.036	1, 2, 2 0.00063	Med	
	Small boat launch/recovery *Operating lifting equipment* Loss of support	2, 2, 3 0.0036	1, 1, 2 0.00036	High	
2. Addition of a new high power radar system	**Not operation/evolution specific** *Providing electronic systems* Electronic systems service quality problems	1, 4, 5 0.0603	1, 4, 5 0.0603	High	No significant affect on risk expected
	Not operation/evolution specific *Providing electronic systems* Radiation exposure	1, 3, 5 0.0333	3, 5, 4 0.333	Med	

Step 1.A Identify the deviations affected by the change and their frequency scores and RINs

Change	Associated Deviation(s)	Initial Frequencies and RIN	Revised Frequencies and RIN Due to the Change	Certainty in Revised RIN	Notes
1. Replacement of the brake and winch on the MSB lifting/ lowering system with a winch capable of payin and payout	**Small boat launch/recovery** *Operating lifting equipment* Incorrect load position/ direction/speed	3, 3, 4 0.036			
	Small boat launch/recovery *Operating lifting equipment* Loss of support	2, 2, 3 0 0036			
2. Addition of a new high power radar system	**Not operation/evolution specific** *Providing electronic systems* Electronic systems service quality problems	1, 4, 5 0.0603			
	Not operation/evolution specific *Providing electronic systems* Radiation exposure	1, 3, 5 0.0333			

Step 1.B Estimate revised Class A/B, Class C, and Class D frequency scores for each deviation affected by the change and calculate new RINs

Change	Associated Deviation(s)	Initial Frequencies and RIN	Revised Frequencies and RIN Due to the Change	Certainty in Revised RIN	Notes
1. Replacement of the brake and winch on the MSB lifting/ lowering system with a winch capable of payin and payout	**Small boat launch/recovery** *Operating lifting equipment* Incorrect load position/ direction/speed	3, 3, 4 0.036	1, 2, 2 0.00063		
	Small boat launch/recovery *Operating lifting equipment* Loss of support	2, 2, 3 0.0036	1, 1, 2 0.00036		
2. Addition of a new high power radar system	**Not operation/evolution specific** *Providing electronic systems* Electronic systems service quality problems	1, 4, 5 0.0603	1, 4, 5 0.0603		
	Not operation/evolution specific *Providing electronic systems* Radiation exposure	1, 3, 5 0.0333	3, 5, 4 0.333		

For each deviation, estimate new frequency scores assuming the change has taken place. It may be necessary to review the coarse hazard analysis tables to understand the causes, mishaps, and safeguards associated with the deviation. Calculate a new RIN using the new frequency scores.

Tip:
$$RIN = (0.3 * 10^{(F_{A/B})} + 0.03 * 10^{(F_{C})} + 0.003 * 10^{(F_{D})})/10{,}000$$

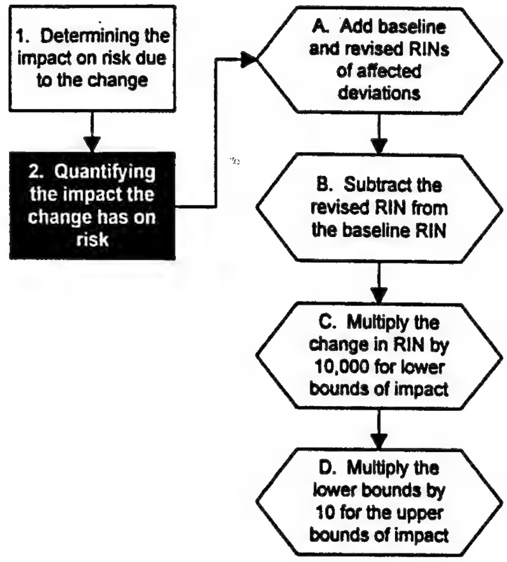
When reviewing the deviations to determine the increase or decrease in frequency scores, ask the following questions:

- How does the change affect administrative procedures and processes?
- How does the change affect existing hardware and systems?
- Does the change improve or reduce the reliability of existing safeguards?
- Does the change eliminate existing safeguards?
- Does the change introduce new hazards?
- Does the change indirectly impact other operations, systems, or processes?

Step 1.C Determine the certainty in the estimate of the revised frequency scores and provide any pertinent notes

Change	Associated Deviation(s)	Initial Frequencies and RIN	Revised Frequencies and RIN Due to the Change	Certainty in Revised RIN	Notes
1. Replacement of the brake and winch on the MSB lifting/ lowering system with a winch capable of payin and payout	**Small boat launch/recovery** *Operating lifting equipment* Incorrect load position/ direction/speed	3, 3, 4 0.036	1, 2, 2 0.00063	Med	
	Small boat launch/recovery *Operating lifting equipment* Loss of support	2, 2, 3 0.0036	1, 1, 2 0.00036	High	
2. Addition of a new high power radar system	**Not operation/evolution specific** *Providing electronic systems* Electronic systems service quality problems	1, 4, 5 0.0603	1, 4, 5 0.0603	High	No significant affect on risk expected
	Not operation/evolution specific *Providing electronic systems* Radiation exposure	1, 3, 5 0.0333	3, 5, 4 0.333	Med	

The certainty characterizes the confidence in the assessment of the frequency scores. The certainty categories are High, Medium, and Low, and are explained in Step 3.B of performing a coarse hazard analysis.



Quantifying the Impact the Change Has on Risk

The cost (negative number) or savings (positive number) due to the impact on risk is calculated by determining the increase or decrease in the RINs for the deviations affected by the change.

Change	Deviation	Baseline RIN	Revised RIN Due to the Change	Change in RIN (positive number is a reduction)	$/Year Change in Risk (positive number = savings)	
					Lower	Upper
1	1	0.036	0.00063			
	2	0.0036	0.00036			
	3	0.36	0.36			
	Total	0.3996	0.36099	0.039	390	3,900
2	1	0.0603	0.0603			
	2	0.0333	0.333			
	Total	0.0936	0.3933	-0.3	-3,000	-30,000

Step 2.A Add baseline and revised RINs of affected deviations

Change	Deviation	Baseline RIN	Revised RIN Due to the Change	Change in RIN (positive number is a reduction)	$/Year Change in Risk (positive number = savings)	
					Lower	Upper
1	1	0.036	0.00063			
	2	0.0036	0.00036			
	3	0.36	0.36			
	Total	0.3996	0.36099			
2	1	0.0603	0.0603			
	2	0.0333	0.333			
	Total	0.0936	0.3933			

Note:
Decision makers will have to consider whether deviations with RIN in the Low certainty category should be used when calculating the $/year impact on risk.

Step 2.B Subtract the revised RIN from the baseline RIN

Change	Deviation	Baseline RIN	Revised RIN Due to the Change	Change in RIN (positive number is a reduction)	$/Year Change in Risk (positive number = savings)	
					Lower	Upper
1	1	0.036	0.00063			
	2	0.0036	0.00036			
	3	0.36	0.36			
	Total	0.3996	0.36099	0.039		
2	1	0.0603	0.0603			
	2	0.0333	0.333			
	Total	0.0936	0.3933	-0.30		

Step 2.C Multiply the change in RIN by 10,000 for the lower bounds of the $/year impact on risk

Change	Deviation	Baseline RIN	Revised RIN Due to the Change	Change in RIN (positive number is a reduction)	$/Year Change in Risk (positive number = savings)	
					Lower	Upper
1	1	0.036	0.00063			
	2	0.0036	0.00036			
	3	0.36	0.36			
	Total	0.3996	0.36099	0.039	390	
2	1	0.0603	0.0603			
	2	0.0333	0.333			
	Total	0.0936	0.3933	-0.30	-3,000	

The equation for calculating RIN is derived using the lower limits of the frequency categories. Multiplying the RIN by 10,000 results in risk values stated in terms of potential dollars on a **yearly** basis. This dollar value is the lower bounds of the estimated impact on risk since it is based on the lower bounds of the frequency categories.

Step 2.D. Multiply the lower bounds by 10 for the upper bounds of the $/year impact on risk

Change	Deviation	Baseline RIN	Revised RIN Due to the Change	Change in RIN (positive number is a reduction)	$/Year Change in Risk (positive number = savings)	
					Lower	Upper
1	1	0.036	0.00063			
	2	0.0036	0.00036			
	3	0.36	0.36			
	Total	0.3996	0.36099	0.039	390	3,900
2	1	0.0603	0.0603			
	2	0.0333	0.333			
	Total	0.0936	0.3933	-0.30	-3,000	-30,000

The frequency categories represent ranges that cover an order of magnitude. Since the RIN equation is derived from the lower frequency bounds, the upper bounds of estimated risk reduction are determined by multiplying the lower bounds by 10. The upper bounds are the maximum estimated $/year impact due to the increase or decrease in risk.

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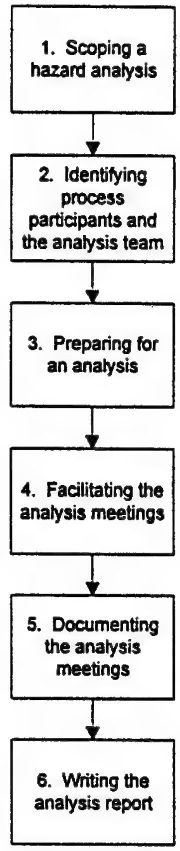
Section 6
Managing a Hazard Analysis Project

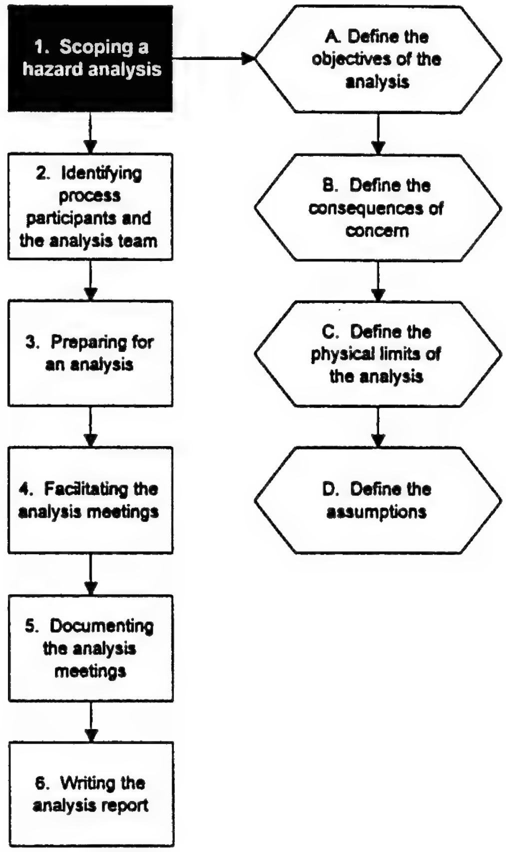


Managing a Hazard Analysis Project

This section provides guidance for coordinating and performing a hazard analysis.

Topics to be discussed:

- Scoping a hazard analysis
- Identifying process participants and the analysis team
- Preparing for an analysis
- Facilitating the analysis meetings
- Documenting the analysis meetings
- Writing the analysis report



Step 1 Scoping a Hazard Analysis

Defining the scope of a hazard analysis is critical to the success of the analysis. A lack of clear direction can waste time and resources examining parts of a process or situations that may be of relatively minor interest or concern.

The scope should provide the boundaries necessary to focus the analysis objectives. However, it is important to define a scope that is not so detailed or restrictive that it stifles the hazard analysis team. The team must have the latitude to exercise good judgment in the investigation of hazards initially outside the scope.

Step 1.A Define the objectives of the analysis

- Determine the motivation for performing the analysis (e.g., Coast Guard management concern, unit concern, public concern, regulatory compliance)
- Determine the operating modes (e.g., operations/evolutions, functions, locations) to be considered
- Develop a "wish list" of information desired from the analysis

Step 1.B Define the consequences of concern

- Public injury
- Coast Guard personnel injury
- Equipment/property damage
- Environmental damage
- Revenue loss
- Community relations

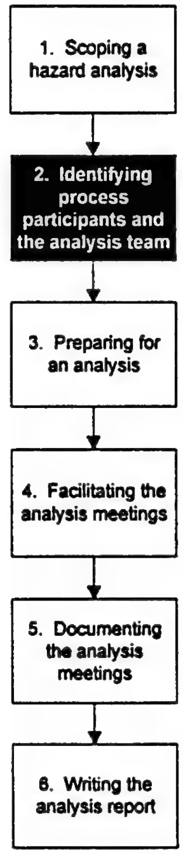
Step 1.C Define the physical limits of the analysis

- Boundaries of the process/operation (e.g., main diesel engine, *providing potable water services*, **towing**, *USCGC MELLON*, WHEC-378s)
- Level of detail/limits of resolution (e.g., coarse hazard analysis or detailed hazard analysis, qualitative or quantitative)

Step 1.D Define the assumptions

Clearly defined assumptions help ensure a consistent analysis. Typical assumptions are as follows:

- The object or process being analyzed will work as designed
- Equipment is fit for its intended use
- Trained Coast Guard personnel will be used
- Written procedures are accurate
- Policies are enforced



Step 2 Identifying Process Participants and the Analysis Team

There are four types of individuals or groups who participate in the hazard analysis process. They include:

Sponsor — This individual or group (e.g., a unit commanding officer, Coast Guard management, unit safety coordinator) determines the need for the analysis to be performed on a particular unit. The sponsor is ultimately responsible for obtaining results from the process and typically has a specific use for the results.

Analyst — This individual or group (e.g., MLC Health and Safety personnel, unit safety coordinator, contractor) is responsible for performing the analysis on a particular unit.

Subject matter experts — This group (e.g., vessel crew, facility staff) participates in the analysis, providing expert knowledge and experience about unit operations, configurations, and hazards.

Decision maker — This individual or group (e.g., vessel command, Coast Guard management, Coast Guard Vessel Safety) uses the hazard analysis process results to make risk-based decisions.

The analysis team consists of **analysts** and **subject matter experts**. Often, a **decision maker** or **sponsor** will kick off the analysis by explaining the importance of the results and how they will be used.

The following provides a more detailed description of the analysis team members:

Analysts — Analysts are either team leaders or scribes.

Team leader *— organizes and facilitates the analysis*

Characteristics:

- Independent of subject process/system (i.e., not the process/ system expert)
- Able to organize and negotiate
- Communicates well with a diverse group
- Can focus group energy and build consensus
- Impartial, honest, and ethical
- Expert in hazard analysis technique(s)

Scribe *— records the proceedings of the analysis in an orderly manner*

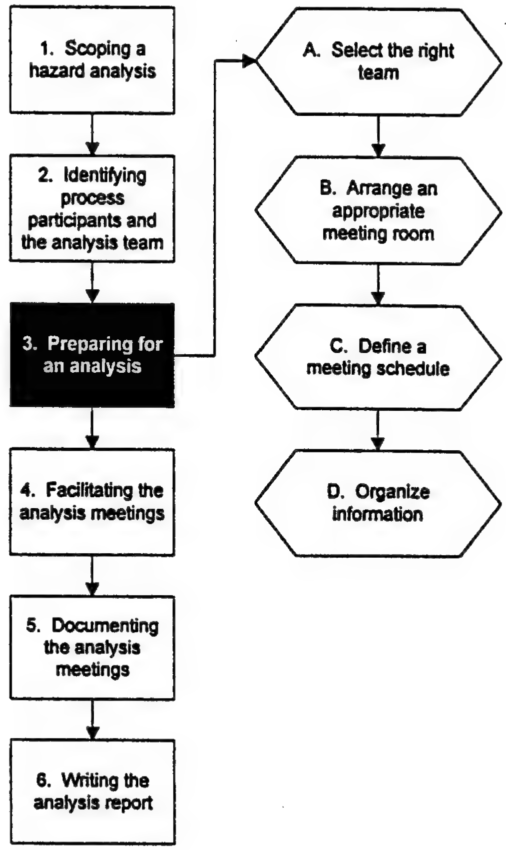
Characteristics:

- Attentive to detail
- Able to organize
- Understands technical terminology
- Able to summarize discussions
- Good writing/typing skills
- Understands the hazard analysis technique(s)

Subject matter experts — Subject matter experts postulate causes, estimate consequences of deviations, identify safeguards, and suggest ways to address unacceptable risks.

Characteristics:

- Enters into the discussion enthusiastically
- Contributes his/her experience
- Confines the discussion to the specific problem
- Listens attentively to the discussion
- Appreciates other team members' points of view



Step 3 Preparing for an Analysis

Preparing for an analysis is just as crucial as performing the analysis. Poor preparation can undermine the analysis. The **analyst(s)** and **sponsor** should work together to ensure that the analysis runs smoothly.

Step 3.A Select the right team

- Team size should be four to eight members
- Team members should have a variety of experience and expertise
- Team members must be objective
- Consider and balance the personality traits of individuals on the team (avoid disruptive people)
- Balance the positions of the individuals on the team (i.e., the captain or facility manager may intimidate some individuals, keeping them from contributing)
- Consider the impact on operations

Step 3.B Arrange an appropriate meeting room

- Room should be large enough to accommodate the team members
- Seating arrangements should be comfortable
- Onsite location that accommodates tours and inspections is ideal (offsite location may be necessary if team members are likely to be interrupted or called out during the analysis)
- Room should be near restrooms and refreshments if possible
- Avoid distractions such as phones, loud speakers, other noises, etc.

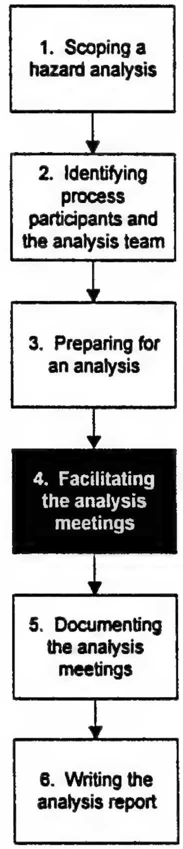
Step 3.C Define a meeting schedule

- Normally, meetings should not exceed 4 to 6 hours per day
- Analysis meetings should normally not last more than 4 or 5 days in a row (typically, large analyses will meet every 2 or 3 weeks)
- The analysis should be scheduled such that there is ample time to document the analysis and resolve the recommendations and/or action items
- Distribute meeting schedules early enough for team members to arrange their own schedules

Step 3.D Organize information

Prepare documentation tools (e.g., worksheets and/or software) — Whether paper or software is used to document the analysis, the documentation tools need to be prepared in advance.

Gather and distribute information on the subject to be analyzed — The team leader should gather all appropriate drawings, procedures, policies, etc., that may be necessary for reference during the analysis. If appropriate, this information can be distributed to the team members before the analysis for their review.



Step 4 Facilitating the Analysis Meetings

The **team leader (analyst)** facilitates the analysis meeting. Proper organization and facilitation make the analysis run smoothly and promote an environment conducive to meeting the analysis objectives. Below are some facilitation tips and issues to consider.

General meeting guidelines

- Introduce the team members
- Review the problem scope and objectives
- Define ground rules for the meeting (e.g., equality of team members, no problem solving)
- Discuss the meeting schedule
- Perform the analysis section by section
- Review results with the team

Questioning techniques for the analysis

- Ask nonthreatening questions:

  "What factors do you emphasize when training new personnel?"

  or

  "What kinds of problems have you seen?"

  not

  "What kinds of mistakes have you made?"
- Treat team members as experts
- Solicit details of past incidents and ask if similar situations could recur
- Direct questions to the quiet team members
- Confine yourself to asking questions, not providing answers

Keys to a successful meeting

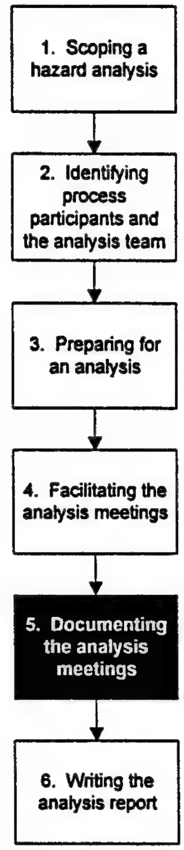
- Listen to all team members
- Promote participation; avoid criticism
- Take frequent breaks to keep energy level high, and limit meetings to 4 to 6 hours per day
- Identify ultimate causes and consequences of deviations
- Keep the meeting moving forward

Common meeting problems to avoid

- Out-of-date documentation
- Ill-defined design intentions, functions, and deviations
- Inadequate information to understand the problem
- Side-tracked discussions
- Digressing into designing solutions

Follow-up activities

- Identify all open items that must be resolved
- Assign a person and schedule for each open item
- Review all recommendations with the team
- Schedule additional meetings as necessary

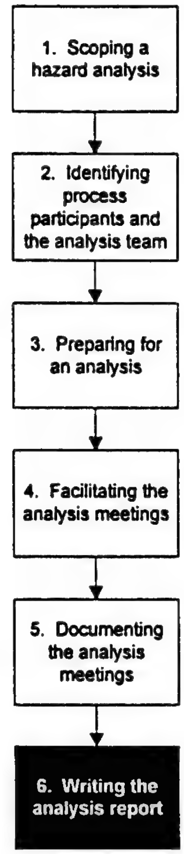


Step 5 Documenting the Analysis Meetings

Each analysis technique has its own method for collecting, organizing, and reporting analysis data. All of these techniques can be performed using paper-based worksheets or electronic software tools (general purpose software or technique-specific tools).

Using dedicated analysis software increases the efficiency of the analysis process, especially in the reporting phase. Some techniques require automation to be practical to use. Eventually, the Coast Guard will have a software package that automates the coarse hazard analysis technique.

Regardless of the method used to document the analysis, it is important that both the team leader and scribe be intimately familiar with the tools and be able to explain to the other team members the documentation process.



Step 6 Writing the Analysis Report

Documenting the results of the analysis provides:

- evidence that the study was performed using sound practices,
- preserves the results for future use,
- supports other activities (e.g., procedures, training, mishap investigation), and
- supports good risk management decisions.

Documentation requirements should be defined before the analysis is performed to ensure that the proper information is collected. Below is a list of the key topics that would be included in a report:

- What was analyzed?
- Which hazard analysis technique was used?
- How were the regulatory requirements met?
- Who performed the analysis?
- What were the action items?
- What was management's response?

The following is an example outline of a hazard analysis report. Reports may be more general or more specific than this outline depending on the intended audience and use of the documentation.

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LIST OF FIGURES

ABSTRACT

SUMMARY

1. INTRODUCTION

2. VESSEL/PROCESS/OPERATION/EQUIPMENT OVERVIEW

3. HAZARD ANALYSIS APPROACH
   - 3.1 Composition of the Team
   - 3.2 Brief Description of the Analysis Technique(s) (e.g., HAZOP, Fault Tree Analysis, Human Reliability Analysis)
   - 3.3 Specific Analysis Issues
     - 3.3.1 Hazards of Interest
     - 3.3.2 Previous Mishaps
     - 3.3.3 Human Factors
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4. HAZARD ANALYSIS RESULTS
   - 4.1 Risk Analysis
   - 4.2 Recommendations
   - 4.3 Concluding Remarks

APPENDIX A: Hazard Analysis Documentation
APPENDIX B: Risk Analysis Documentation
APPENDIX C: Risk Reduction Measures
APPENDIX D: Report Reference Material

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Section 7
Detailed Hazard Analysis

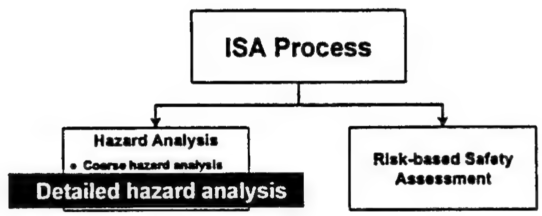
The IRA Detailed Hazard Analysis

- Introduction
- Choosing coarse or detailed hazard analysis
- Selecting a detailed hazard analysis technique
- Estimating resources for a detailed hazard analysis

The IRA Detailed Hazard Analysis

- Introduction
- Choosing coarse or detailed hazard analysis
- Selecting a detailed hazard analysis technique
- Estimating resources for a detailed hazard analysis

Detailed Hazard Analysis



The goal of Coast Guard detailed hazard analysis is to supplement the coarse hazard analysis methodology for situations in which more detail is warranted. The detailed hazard analysis tools included in the IRA process are standard hazard/risk analysis techniques that have been proven through many years of application in a variety of industries. The following is a list of the detailed hazard analysis techniques chosen for Coast Guard use.

Detailed hazard analysis techniques for Coast Guard applications

- What-if/checklist
- Worker and instruction safety evaluation (WISE) analysis
- Hazard and operability (HAZOP) analysis
- Failure modes and effects analysis (FMEA)
- Fault tree analysis/event tree analysis (FTA/ETA)
- Human reliability analysis (HRA)
- Common cause failure analysis (CCFA)

Section 3, Overview of Common Hazard/Risk Analysis Methodologies, provides a brief description and example of each of these techniques. The following table is the Coast Guard rationale for selecting detailed hazard analysis and specific detailed hazard analysis techniques.

Technique	Rationale for Selection
What-if/Checklist	The simplicity and universal applicability of what-if/checklist analysis made it a natural choice for detailed hazard analysis within the Coast Guard
Worker and Instruction Safety Evaluation (WISE) Analysis	The extensive nature of human involvement (especially procedural tasks) in virtually every Coast Guard mission/operation makes tools for thoroughly evaluating human error very important. The WISE analysis methodology combines into one technique an awareness of how people can impact processes and how processes can affect people
Hazard and Operability (HAZOP) Analysis	This technique is similar in nature to WISE, but is more applicable to fluid and thermal systems, which are abundant on Coast Guard vessels. It provides a more structured approach than a what-if/checklist analysis to identifying hazard and operability problems stemming from system deviations
Failure Modes and Effects Analysis (FMEA)	The Coast Guard uses mechanical and electrical systems/equipment extensively, making FMEA a natural choice for these applications when a less structured what-if/checklist analysis may be inadequate. (Although HAZOP analysis could be useful for analyzing Coast Guard fluid and thermal systems, FMEA can be equally effective in such applications for Coast Guard systems)
Fault Tree Analysis/ Event Tree Analysis (FTA/ETA)	Because the Coast Guard has several systems with built-in redundancy and multiple levels of safeguards, modeling techniques for identifying complex combinations of equipment failures and human errors will be important for some situations. FTA/ETA are the most widely recognized and universally applicable techniques for these situations
Human Reliability Analysis (HRA)	The importance of human errors in Coast Guard operations and the complexity of some operations/procedures make HRA potentially useful for special situations as a supplement to other techniques (especially WISE analysis)
Common Cause Failure Analysis (CCFA)	When a situation is complex enough to require FTA/ETA, the potential for common cause failures cannot be overlooked. CCFA should always be applied (in some level of detail) with FTA/ETA

The IRA Detailed Hazard Analysis

- Introduction
- Choosing coarse or detailed hazard analysis
- Selecting a detailed hazard analysis technique
- Estimating resources for a detailed hazard analysis

Choosing Coarse or Detailed Hazard Analysis

Although coarse hazard analysis will meet a large portion of the Coast Guard's hazard/risk needs, more detailed analysis of hazards/risks is needed in some circumstances. Fundamentally, more detailed analysis is warranted when:

- better resolution of potential mishap scenarios is needed (e.g., more specific descriptions of causes and safeguards) and
- more certainty is needed in the risk characterizations for selected mishap scenarios (e.g., there was a low level of certainty in the coarse hazard analysis results).

The IRA Detailed Hazard Analysis

- Introduction
- Choosing coarse or detailed hazard analysis
- Selecting a detailed hazard analysis technique
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Key Factors in Selecting a Technique

Motivation for analysis

This consideration should be the most important to every hazard/risk analyst. Performing a hazard/risk analysis without understanding its motivation and without having a well-defined purpose is likely to waste valuable process/mission improvement resources. A number of issues can shape the purpose of a given analysis. For example, what is the impetus for performing the analysis in the first place? Is the analysis being done as part of a policy for performing hazard/risk analyses of new processes/products? Are insights needed to make risk management decisions concerning the improvement of a mature, existing process/mission? Or is the analysis being done to satisfy a regulatory or legal requirement? Individuals responsible for selecting the most appropriate technique and assembling the necessary human, technical, and physical resources must be provided with a well-defined, written purpose so that they can efficiently execute the analysis' objective.

Types of results needed

The *type* of results needed is important for actually choosing an analysis technique. Depending on the motivation for the hazard/risk analysis, a variety of results could be needed to satisfy the study's charter. Defining the specific type of information needed to satisfy the objective of the analysis is an important part of selecting the most appropriate analysis technique. The following are five categories of information that can be produced from most hazard/risk analyses:

- List of potential mishaps
- List of how these mishaps occur (i.e., failure modes, causes, sequence)
- List of alternatives for reducing the potential for these mishaps

- List of areas needing further analysis and/or input for a quantitative analysis (which addresses our "depth of analysis" scoping strategy)
- Prioritization of results

Some hazard/risk analysis techniques can be used solely to identify the critical problem areas associated with a process or mission. If that is the only purpose of the analysis, then a technique can be selected that will provide a list or a "screening" of areas of the process/mission that possess the potential for mishaps.

Nearly all of the analysis techniques can provide lists of how these mishaps occur and possible risk reduction alternatives (i.e., action items). Several of the techniques can also be used to prioritize the action items based on the team's perception of the level of risk associated with the situation that the action item addresses.

Types of resources available

Two primary conditions define what information is available to the analysis team: (1) the stage of life the process or product is in when the analysis needs to be performed and (2) the quality and currentness of the available documentation.

The first condition is generally fixed for any hazard/risk analysis. The process' or mission's stage of life establishes the practical limit of detailed information available to the analysis team. For example, if a hazard/risk analysis is to be performed on the conceptual design of a process, it is highly unlikely that an organization will have already produced piping and instrumentation diagrams (P&IDs) or detailed design drawings for the proposed process or product. Thus, if the analyst must choose between HAZOP analysis and what-if analysis, then this "phase-of-life" factor would dictate a less detailed analysis technique (i.e., the what-if analysis).

The second condition deals with the quality and currentness of the documentation that does exist. For a hazard/risk analysis of an existing process, analysts may find that the P&IDs are not up to date or do not exist in a suitable form. Using any analysis technique with out-of-date information is not only futile, it is a waste of time and resources. Thus, if all other factors point to using a specific technique for the proposed analysis that requires such information, then the analysts should ask management to have the necessary, up-to-date information available.

Complexity and size of analysis

Some techniques can get bogged down when used to analyze extremely complicated problems. The complexity and size of an analysis are functions of:

- the number of systems being analyzed,
- the number of pieces of equipment in each system,
- the number of operating steps, and
- the number and types of events and effects being analyzed.

For many analysis techniques, considering a larger number of equipment items or operating steps will increase the time and effort needed to perform a study. For example, using the FMEA technique will generally take 5 times more effort for a system containing 100 equipment items than for a system containing 20 items. Thus, the types and number of events and effects being evaluated are proportional to the effort required to perform a hazard/risk analysis, although in some cases it may not be a linear relationship.

Types of system/operations

Many techniques can be used for almost any type or combination of system types. However, certain techniques are better suited for particular systems than others. For example, the FMEA approach has a well-deserved reputation for efficiently analyzing mechanical, electronic, and computer systems, whereas the HAZOP analysis approach may not work as well for these types of systems. In addition, some techniques are more applicable for analyzing at the component and piece-part level instead of analyzing at a system level.

Types of loss events targeted

Organizations tend to use more systematic techniques for those systems that they believe pose higher risk (or, at least, for situations in which failures are expected to have severe consequences). Thus, the greater the perceived risk of the system, the more important it is to use techniques that minimize the chance of missing an important potential mishap.

Selecting a Technique

The following table provides a summary of key characteristics of the Coast Guard detailed hazard analysis techniques.

Hazard Evaluation Technique	Analysis Type		Types of Results				Types of Systems	Level of Effort/ Complexity	Level of Training for Analysts and Analysis Teams
	Deductive	Inductive	Qualitative Mishap Descriptions	Quantitative Risk Charac-terizations	Relative Importance of Mishap Contributors	Recommend-ations			
What-if/ Checklist Analysis		✓	✓			✓	All	Medium	Low to Medium
WISE Analysis		✓	✓			✓	Sequential operations and procedures	Medium to High	Medium
HAZOP Analysis		✓	✓			✓	Process systems, especially fluid and thermal systems Sequential operations and procedures	Medium to High	Medium
FMEA		✓	✓	✓	✓	✓	All, especially mechanical and electrical systems	Medium to High	Medium
FTA	✓		✓	✓	✓	✓	All	High	Medium to High
ETA		✓	✓	✓	✓	✓	All	High	Medium to High
HRA		✓	✓	✓	✓	✓	Sequential operations and procedures	High	Medium to High
CCFA	✓		✓	✓	✓	✓	All	High	Medium to High

The matrix below will help in determining the appropriate detailed hazard analysis technique to use. Choose a detailed hazard analysis technique that best fits the characteristics of the issue to be analyzed.

Characteristics of the Issue Being Analyzed	What-If/Checklist	WISE Analysis	HAZOP Analysis	FMEA	FTA	ETA	HRA	CCFA
Detailed design information is unavailable	✓							
A good experience base is unavailable		✓	✓	✓	✓	✓	✓	✓
The process/operation includes human action, and human errors are of greatest concern		✓					✓	
Qualitative analysis is required	✓	✓	✓	✓	✓	✓	✓	✓
Quantitative analysis is required				✓	✓	✓	✓	✓
Accidents are likely to be single failure events	✓	✓	✓	✓				
Accidents are likely to be multiple failure events					✓	✓	✓	✓
The process is a mechanical or electrical system				✓	✓	✓		✓
An exhaustive list of failure modes is required			✓	✓	✓	✓	✓	✓

The IRA Detailed Hazard Analysis

- Introduction
- Choosing coarse or detailed hazard analysis
- Selecting a detailed hazard analysis technique
- Estimating resources for a detailed hazard analysis

Estimating Resources for a Detailed Hazard Analysis

Different analysis techniques require different levels of time commitment to perform. This section presents the estimated time required to perform the various stages of the Coast Guard detailed hazard analysis techniques.

What-if/Checklist Analysis

SUMMARY OF WHAT-IF/CHECKLIST REVIEW

Process and Location: *WHEC-378*

Topic Investigated: *Refueling*

Equipment/Task Intentions: *Fuel System*

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What If . . .?	Causes	Consequences	Safeguards	Action Items
1. What if the diesel tank is overfilled?	High or uncontrolled flow rates from fueling source	Spill of diesel fuel	Overflow tank Tank level indicators Fuel vents to atmosphere	Consider installing fast-acting valves in the fuel supply lines

Scope	Preparation	Evaluation	Documentation
Simple/small system	6 to 12 hours	6 to 12 hours	4 to 8 days
Complex/large process	1 to 3 days	4 to 7 days	1 to 3 weeks

Hazard and Operability (HAZOP) Analysis

HAZOP of Refueling System

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Section: *1.0 Fuel Hose*

Drawing Number: *USCG34-8211*

Revision Number: *2*

Item	Deviation	Causes	Consequences	Safeguards	Recommendations
1.1	High pressure	Blockage in the fuel line Flow valve closed Blocked sounding tube and vents	Rupture of the fuel hose and fittings Potential ignition of spilled fuel	Overflow valves Watchstander	Consider improving procedures used to align flow valves
1.2	Misdirected flow	Flow control valves misaligned	Rupture of fuel hose and fittings Potential ignition of spilled fuel	Overflow valves Watchstander	Consider improving procedures used to align flow valves

Scope	Preparation	Evaluation	Documentation
Simple/small system	8 to 12 hours	1 to 3 days	2 to 6 days
Complex/large process	2 to 4 days	1 to 3 weeks	2 to 6 weeks

Failure Modes and Effects Analysis (FMEA)

FMEA of Fuel Oil Supply for Onboard Incinerator

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Equipment: *Fuel Oil Supply Line A-28*

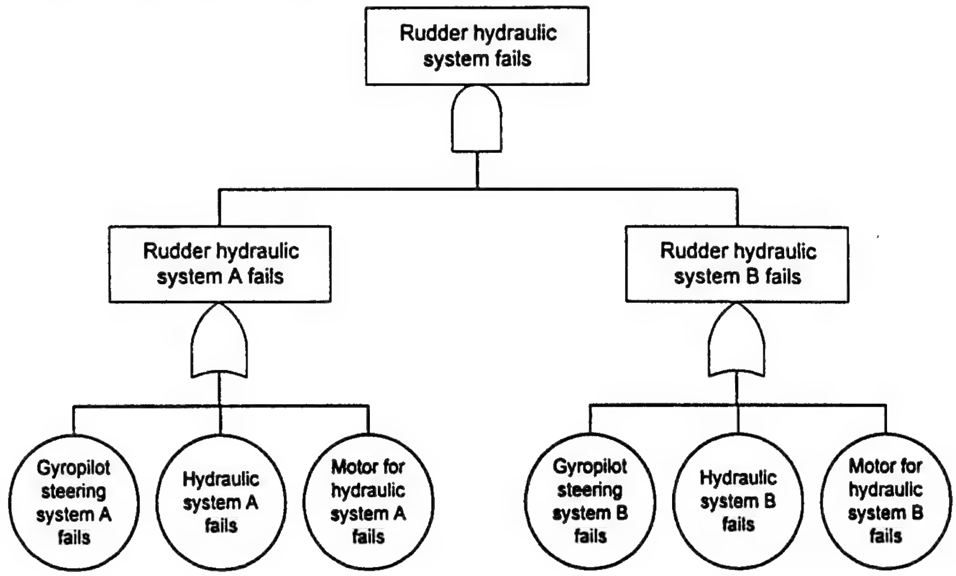
Drawing Number: *USCG599-71340*

Revision Number: *2*

Item	Failure Modes	Effects	Safeguards	Actions
1.1	Plugs	Low fuel oil flow	Supply line filter/strainer	Consider preventive maintenance on the supply line, including the filter and strainer
1.2	External leak	Release of fuel oil	Periodic inspection of fuel oil system	
		Potential fire hazard	High pressure portion of fuel oil piping is short run from pump discharge to injectors	

Scope	Preparation	Evaluation	Documentation
Simple/small system	2 to 6 hours	1 to 3 days	1 to 3 days
Complex/large process	1 to 3 days	1 to 3 weeks	2 to 4 weeks

Fault Tree Analysis (FTA)



Scope	Preparation	Model Construction	Qualitative Evaluation	Documentation
Simple/small system	1 to 3 days	3 to 6 days	2 to 4 days	3 to 5 days
Complex/large process	4 to 6 days	2 to 3 weeks	1 to 4 weeks	3 to 5 weeks

Worker and Instruction Safety Evaluation (WISE) Analysis

WISE Analysis of

Procedure/Instruction: *RHI Lowering and Hoisting Procedures*

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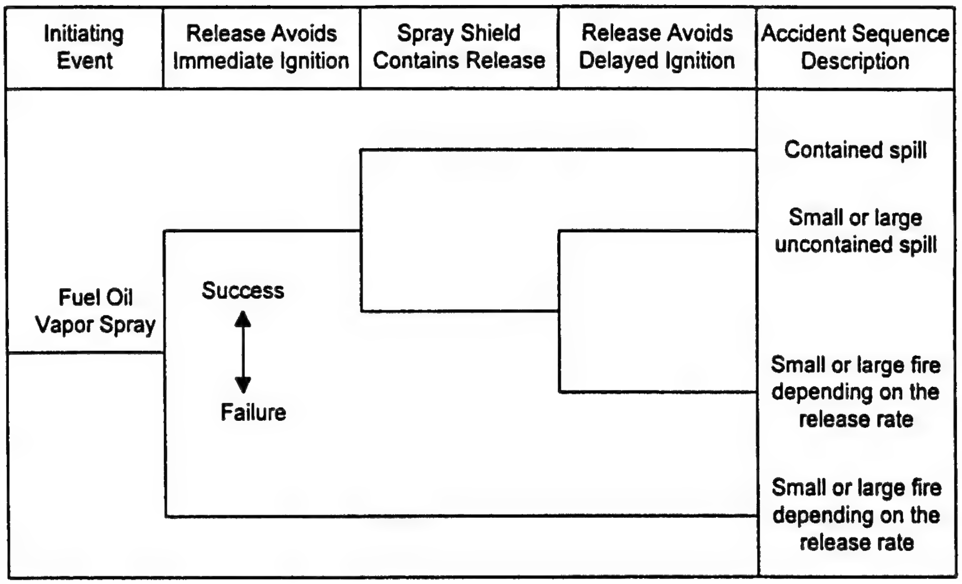
Job Step	WISE-guides	Causes	Potential Consequences	Safeguards	Suggested Improvements
1	Less	Deck supervisor misjudges distance RHI moved out	RHI damaged when lowered to the rail	Involvement of multiple people on deck makes lowering RHI onto rail extremely unlikely	Consider adding a visual aid to indicate when the MSB/RHI has been breasted out to correct position prior to putting it to the rail
2	More	Deck supervisor orders RHI swung out too fast Articulating crane operator accidently moves RHI out too fast	Personnel injury		

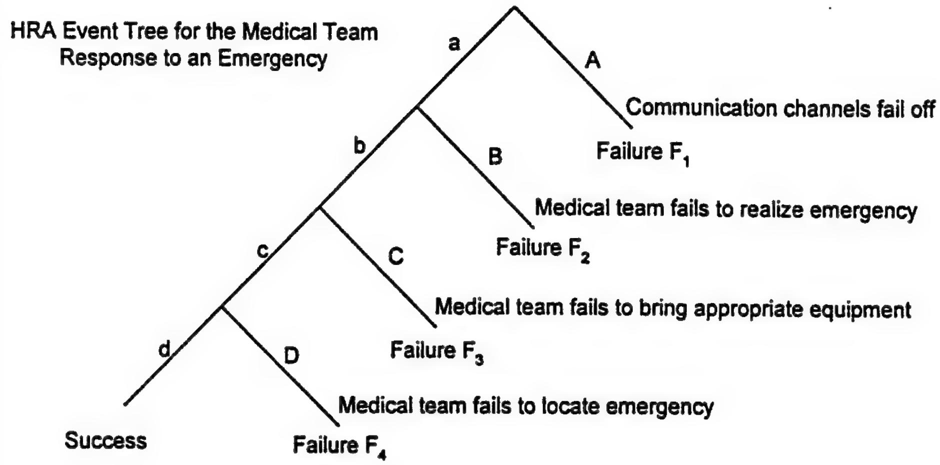
Scope	Preparation	Evaluation	Documentation
Simple/small operation	2 to 4 hours	2 to 4 hours	1 to 2 days
Complex/large operation	4 to 8 hours	1 to 5 days	3 to 10 days

Event Tree Analysis (ETA)



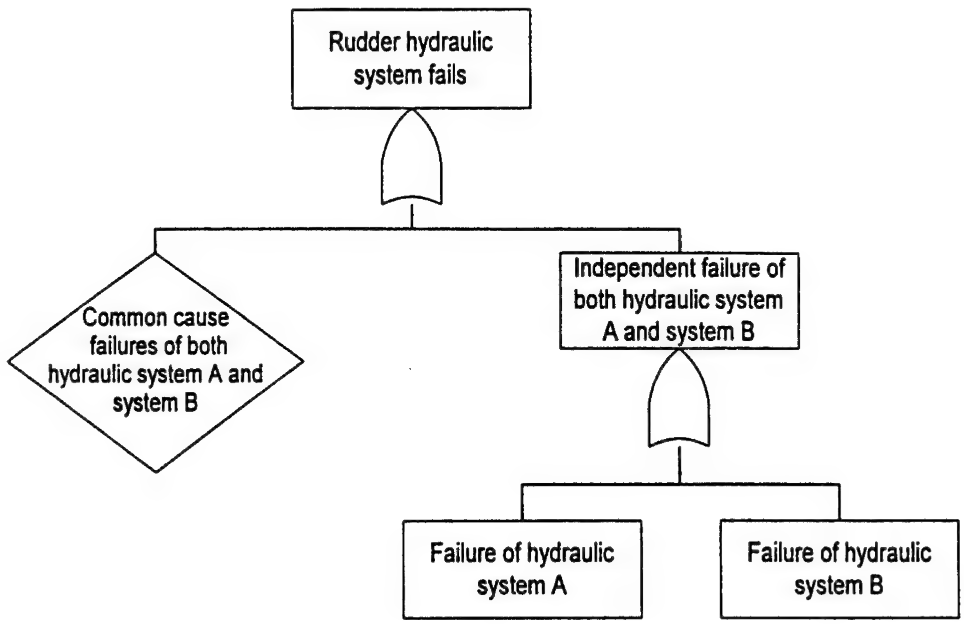
Scope	Preparation	Model Construction	Qualitative Evaluation	Documentation
Simple/small system	1 to 2 days	1 to 3 days	1 to 2 days	3 to 5 days
Complex/large process	4 to 6 days	1 to 2 weeks	1 to 2 weeks	3 to 5 weeks

Human Reliability Analysis (HRA)



Scope	Preparation	Model Construction	Qualitative Evaluation	Documentation
Simple/small system	4 to 8 hours	1 to 3 days	1 to 2 days	3 to 5 days
Complex/large process	1 to 3 days	1 to 2 weeks	1 to 2 weeks	1 to 3 weeks

Common Cause Failure Analysis (CCFA)



Scope	Preparation*	Evaluation*	Documentation*
Simple/small system	4 to 8 hours	4 to 8 hours	1 to 2 days
Complex/large process	1 to 3 days	1 to 3 days	2 to 5 days

*In addition to use of another technique (such as fault tree analysis)

United States Coast Guard
IRA Manual

Section 8
Risk-based Safety Survey

The IRA Risk-based Safety Survey

- Introduction
- Performing a risk-based safety survey
- Maintaining the risk-based safety survey process
- Information exchange between the risk-based safety survey and the coarse hazard analysis
- Using the risk-based safety survey to update the coarse hazard analysis
- Making decisions using the IRA risk-based safety survey

The IRA Risk-based Safety Survey

- **Introduction**
- Performing a risk-based safety survey
- Maintaining the risk-based safety survey process
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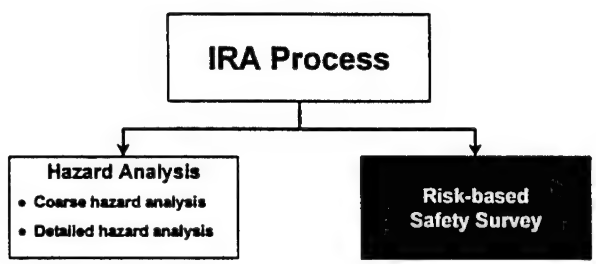
- Making decisions using the IRA risk-based safety survey

Introduction

The IRA risk-based safety survey process



Risk-based safety surveys help manage risk by ensuring that the safeguards designed to control the risk of potential mishaps are being effectively implemented. The risk-based safety survey process performs much the same function as typical field surveys historically performed by the Coast Guard with the following notable exceptions:

- Better focus on the most significant risks
- More objective prioritization of findings
- More efficient use of assessment resources
- Investigation of root causes of findings
- Characterization of safeguard dependability
- Improvement of Coast Guard standards and requirements

The IRA Risk-based Safety Survey

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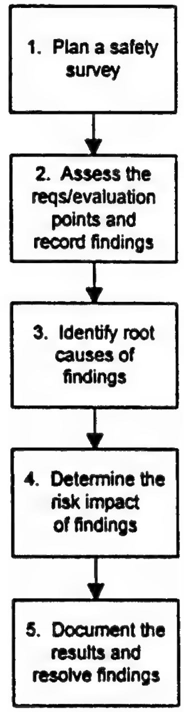
- Making decisions using the IRA risk-based safety survey

Performing a Risk-based Safety Survey

***Risk-based safety survey** — a survey that (1) proportionately applies field verification resources to evaluation points that most effectively assess the status of the most important safeguards (i.e., higher risk issues receive more resources) and (2) facilitates timely correction of significant deficiencies and their underlying root causes.*

Performing a risk-based safety survey involves all of the activities necessary for assessing the condition of a unit with respect to a set of Coast Guard requirements (as well as other defined safeguards important for risk control) and analyzing/documenting the results.



Overview of the Steps for Performing a Risk-based Safety Survey

This section outlines the steps for performing a risk-based safety survey.

1. Plan a safety survey

Planning a survey involves:

- Identifying the scope of the survey
- Preparing for the survey

2. Assess the requirements/evaluation points and record findings

This task is the actual survey of the unit. Survey team members canvass the unit, reviewing evaluation points. The survey includes equipment inspections, personnel interviews, and documentation reviews.

3. Identify root causes of findings

Determining the underlying causes of a deficiency and correcting them helps to ensure that the deficiency does not occur again and prevents the underlying causes from contributing to other types of deficiencies and mishaps.

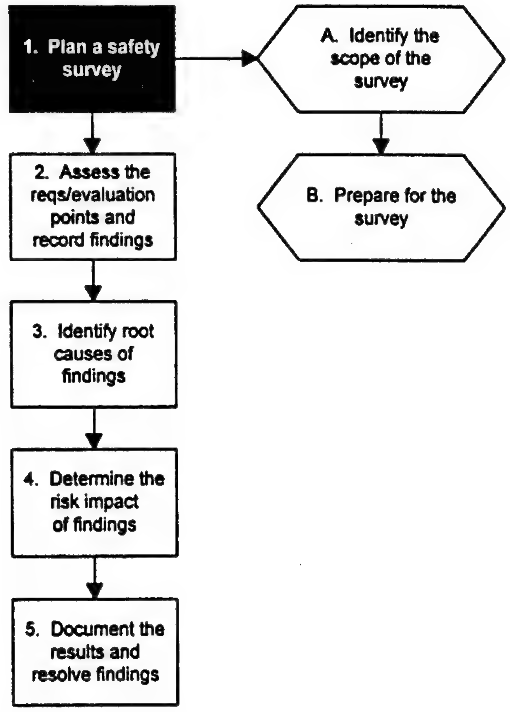
Root cause analysis should be performed at some level of detail for each finding. For some findings the simple question "why?" is enough to determine a root cause. Other findings may require more rigor (e.g., 5 Whys technique, Root Cause Map™ technique) to find the root causes. The level of detail and the number of findings investigated with root cause analysis is left to the discretion of the survey team.

4. Determine the risk impact of findings

This step of the process involves assigning a relative risk weighting to each finding that characterizes the finding's potential impact on unit risk. Risk impact is the foundation for prioritizing the findings for resolution and other tasks in the safety survey process.

5. Document the results and resolve findings

The safety survey visit is concluded with an outbrief highlighting the results of the survey. The results are also documented in a safety survey report that is submitted to the unit command, and the findings are documented in a findings database.



Step 1 Plan a Safety Survey

Planning a safety survey is very important to the success of the survey. Preparation involves coordinating the survey activities with the unit command, preparing the survey team for the survey, and performing the survey inbrief.

Step 1.A Identify the scope of the survey

Identifying the scope of the safety survey involves determining which group of evaluation points will be assessed. A survey will include all evaluation points at some level of risk significance (e.g., all high and medium risk evaluation points) as well as other lower risk evaluation points of interest to the survey sponsor/host.

Example
A survey has been planned to review only the issues with high risk significance; however, the CO requests that eyewash stations be checked for proper location (historically a lower risk significance item) due to some confusion with interpreting a requirement. Also, new electrical equipment in the galley will be checked for proper grounding due to a recent mishap at a similar unit.

The following table is an example of a scope for a safety survey. The justification and comments column explains why additional evaluation points were added for this survey. Originally, this survey was only to review issues with high risk significance.

Evaluation Area	Evaluation Points*	Justification and Comments
Occupational Medical Monitoring Program	A1, A2, A3, A5, A6, A10, A11, A13	Checking these items due to recent change of command
Heat Stress Program	B1, B2, B5, B6, B8, B9, B10	
Hearing Protection	C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12	
Eye Protection	D1, D5, D6, D7, D8, D9	
Respiratory Protection	E1, E2, E6, E9, E10, E11, E12	Checking these items due to mishaps listed in recent message traffic
Asbestos	F1, F2, F4, F5, F6, F7, F8, F9, F15	
Respiratory Protection	G1, G2, G6, G7, G9, G10, G11, G12	
Food Preparation Spaces	H1, H2, H3, H4, H5, H6, H7, H10, H11, H13, H14, H15, H17, H20, H22, H23, H24, H28	Checking these items due to request from Unit CO
Safety Program Administration	J1, J2, J3, J4, J5, J6, J7, J8, J9, J10, J11, J12, J13, J14, J15, J16	
Electrical Safety	K1, K4, K5, K6, K7, K9, K10, K11, K12, K13, K16, K17, K19, K20, K22, K33, K35, K38, K39, K41, K42, K44	

*This survey is of the evaluation points with high risk significance and additional evaluation points as specified in the justification and comments

Step 1.B Prepare for the survey

There are several preparatory activities that are necessary for a successful survey. These activities are as follows:

Review information related to the survey scope

The survey team members should be familiar with current and historical information related to the survey they are planning to perform. Knowledge of this information will improve the effectiveness and efficiency of the survey. This information includes:

- the safety survey checklist that will be used during the survey,
- past mishaps and findings for the unit class and unit being surveyed,
- the coarse hazard analysis information for the specific unit class (high level review), and
- applicable requirements that form the basis for the evaluation points within the scope of the survey.

Coordinate the survey schedule with the unit

Work with the unit command to develop a preliminary schedule for the inbrief, the actual survey, and the outbrief.

Arrange for appropriate unit personnel to support the survey

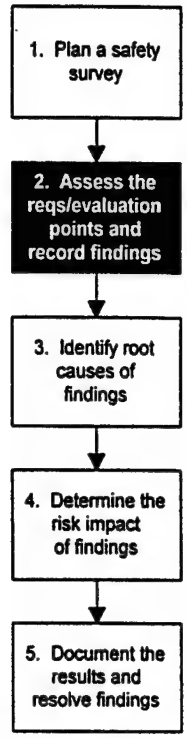
The survey team should identify the unit personnel required for the survey as well as the length of time the unit personnel will be required. The use of these individuals' time should be coordinated with the unit command.

Assemble a survey team with experience that matches the content of the survey to be performed

To be most effective and efficient, the survey team members should be experts in the subject areas reviewed during the survey (or at least involve such experts in their survey).

Plan the survey inbrief

The purpose of the inbrief is to kick off the safety survey with unit management by introducing the participants (survey team and unit personnel), briefly discussing the activities surrounding the safety survey process, and providing a proposed schedule of activities.



Step 2 Assess the Requirements/Evaluation Points and Record Findings

This activity involves actual field assessment of evaluation points (or in some cases the requirements themselves). These assessments typically include:

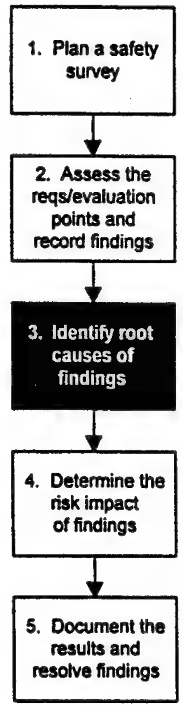
- Equipment inspections
- Personnel interviews
- Documentation reviews

Because every specific implementation of each requirement/evaluation point cannot realistically be observed during these surveys, survey teams must select a few representative instances to evaluate (i.e., sampling). The risk significance of an evaluation point obviously influences how many and what types of field checks a survey team chooses to perform (e.g., 100% of a certain type of critical component might be assessed, while only 10% of a less critical type of component might be assessed).

Note:
The actual choices of sampling plans (i.e., which specific equipment to check, people to interview, and documents to review) are left to the discretion of survey teams, who use the risk significance of evaluation points, as well as their own experience, as a guide.

Deficiencies identified during the safety survey are noted as findings. Typical information to record concerning a finding includes:

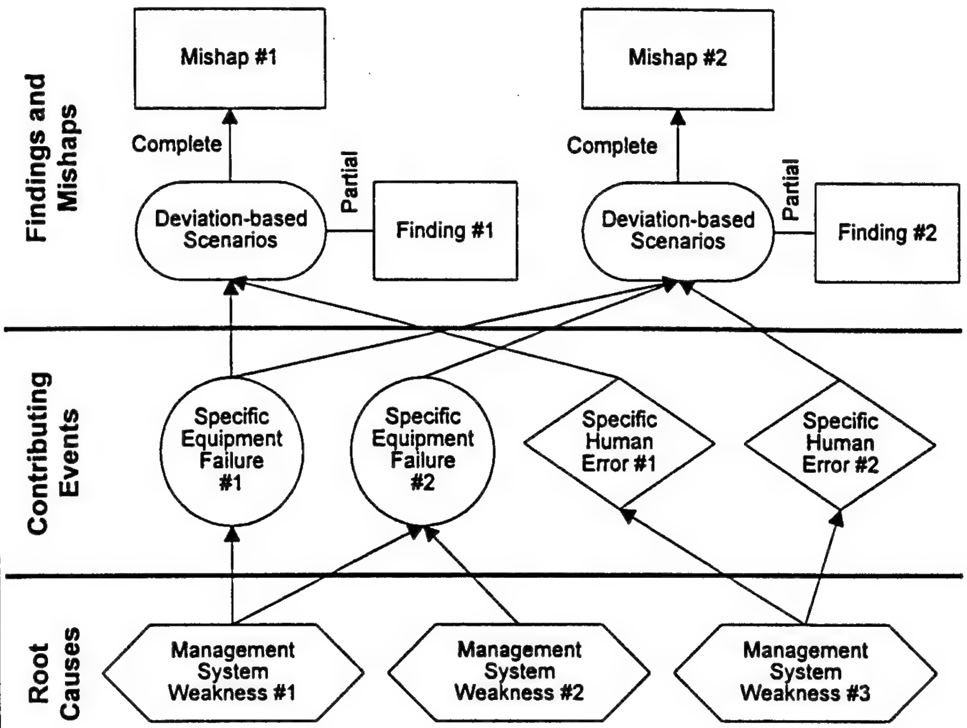
- the associated requirement/evaluation point,
- whether the deficiency appears to be an isolated case or not,
- contributing causes of the deficiency, and
- the location of the deficiency at the unit.



Step 3. Identify Root Causes of Findings

Root causes *— the most basic causes of an event that (1) can be reasonably identified and (2) management has control/influence to fix.*

Root cause analysis investigates the underlying problems that allowed a deficiency to occur and to continue to exist until the survey was performed. The analysis helps ensure that a specific deficiency does not occur again. It also helps ensure that the underlying problems do not contribute to various other types of deficiencies and/or mishaps (perhaps seemingly unrelated to the current situation).



Through a systematic process, survey team members try to identify management system weaknesses that contributed to deficiencies so that those weaknesses can be corrected (not to assign blame to managers). Management system weaknesses are the focus because vulnerabilities that allow equipment to fail and error-likely situations that cause human mistakes are generally traced to fundamental management system weaknesses.

Note:
Root cause analysis goes beyond understanding the scenario of events that led to the deficiency. More investigation of the underlying problems is required to find and correct the underlying management problems that will contribute to future deficiencies if not corrected.

It is preferable that root cause analysis is performed on all of the findings at some level of detail. However, survey teams may decide to only perform an analysis on selected findings (e.g., the findings that by themselves represent a large increase in risk or those thought to indicate broadly systemic problems).

There are several techniques available to perform a root cause analysis. Three of these techniques are (1) engineering/expert judgment, (2) the 5 Whys technique, and (3) the JBF Associates, Inc. (JBFA) Root Cause Map technique.

Selected Techniques for Finding Root Causes

- Engineering/expert judgment
- 5 Whys technique
- JBFA Root Cause Map technique

Selecting Techniques for Finding Root Causes

Engineering/expert judgment

- Most common approach in use today
- Dependent on analyst's/team's experience, background, and understanding of root causes
- Not auditable for thoroughness
- Not inherently consistent or reproducible

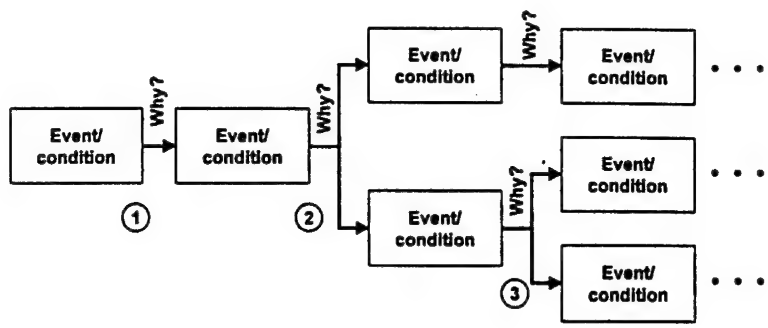
5 Whys technique

The 5 Whys technique is a brainstorming-type technique for identifying root causes of problems by questioning *why* events occurred or conditions existed

Root Cause Map technique

- Originally derived from the Department of Energy's (DOE's) management oversight and risk tree (MORT) for DOE's Savannah River Laboratory
- Structures the reasoning process for identifying root causes
- Identifies detailed root causes for each major root cause category
- Promotes consistency across all root cause investigations
- Supports trending of root causes

The 5 Whys



5 Whys Technique

The 5 Whys technique is a brainstorming-type technique for identifying root causes of problems by questioning *why* events occurred or conditions existed

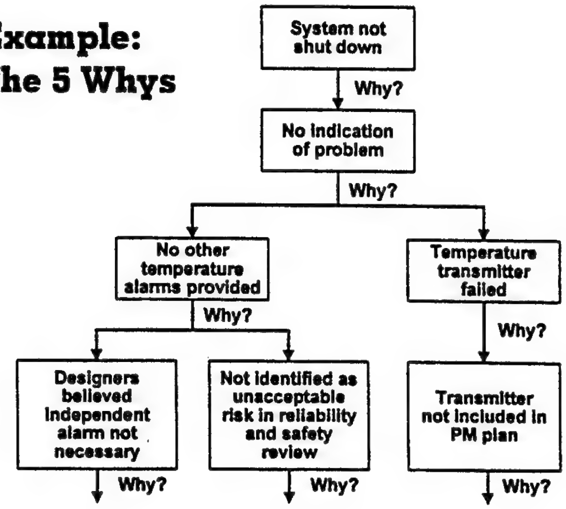
Using the 5 Whys

- Select one event associated with a problem situation
- Ask why this event occurred (i.e., the most direct cause of the event)
- Solicit answer(s) to this question (the answer may identify more than one subevent or condition as the cause)
- For each of these subevents or causes, ask why it occurred
- Solicit answers to these why questions and repeat the process through at least three more iterations of why questions
- Repeat the process for the other events associated with the problem situation

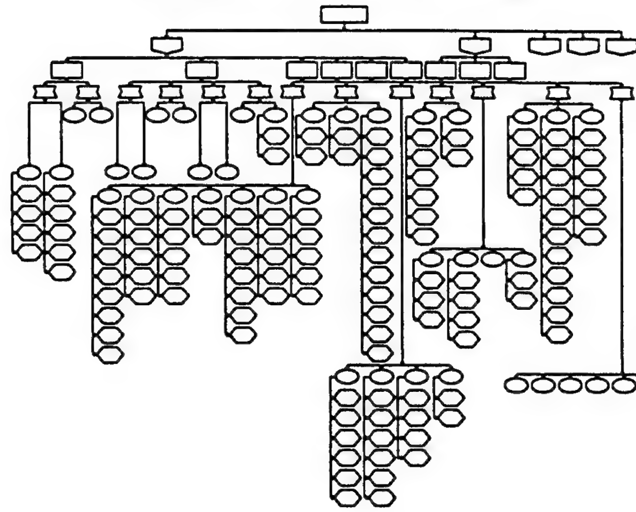
Conclusions about 5 Whys

- Resulting subevents/conditions should be at or near the root causes of the event
- More or less detailed evaluation may be necessary for some cases to reach management system root causes
- Judgment and experience are key factors in selecting the right level of evaluation and completeness
- This technique can be time consuming compared to other techniques that don't require brainstorming
- The results are not inherently reproducible/consistent, but the application is auditable

Example: The 5 Whys



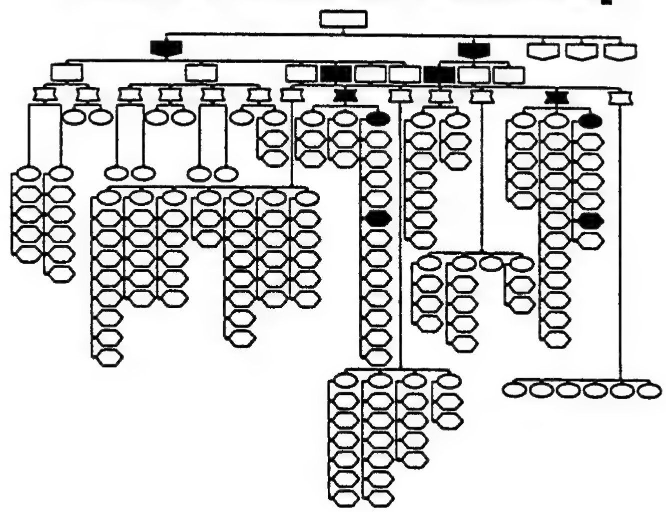
JBFA Root Cause Map



Observations About the Structure of the Map

- Items most closely associated with hardware/engineered systems appear toward the left side of the map, while items most closely associated with personnel appear toward the right side of the map
- Moving from left to right on the map parallels the progression of system development (i.e., beginning with equipment design and progressing through operations management and personal performance)
- Some segments of the map are not resolved to "root causes" to maintain consistency in the level of detail with other segments of the map (further expansion is certainly acceptable)
- Different arrangement of the map would not change the fundamental use of the map as a graphical checklist to help provide a comprehensive search for root causes
- Various organizations may need to slightly modify the map structure/terminology to mesh with their organizational culture and management systems

Structure of the Root Cause Map

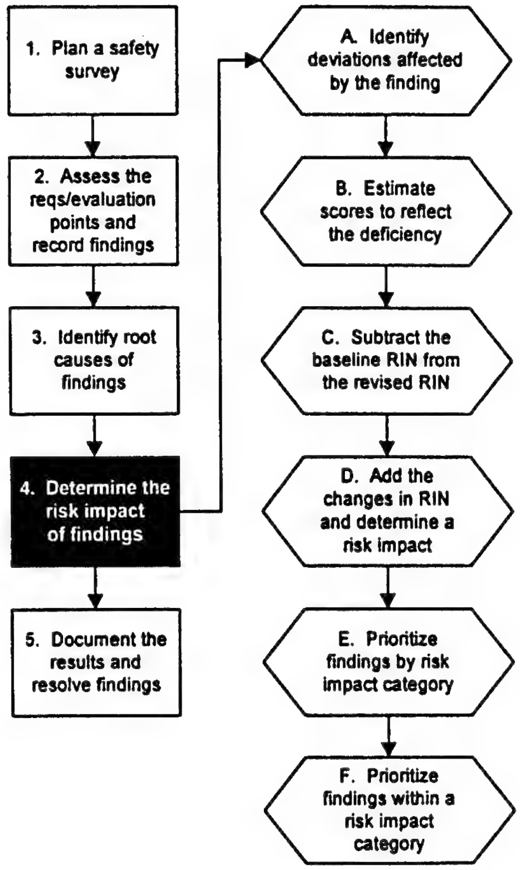


Using the Map

- Select a finding
- Work through the map for each finding
- Step down root path(s), noting
  - primary difficulty source (equipment, personnel, other),
  - problem category,
  - major root cause category,
  - near root cause, and
  - root cause.
- Record results on forms at each step
- Perform 5 Whys if root causes are not deep enough
- Use root causes for
  - generating recommendations and
  - trending.

Example

Finding	Paths Through the Root Cause Map	Recommendations
No defined guidance for ensuring personnel in charge of the respirator program receive training in administering the program Background: Respirator administration was recently turned over to a junior person. This person performs the actual duties of the respirator program, but has not been fully trained on documenting the program. Supervisory personnel are also not fully cognizant of the program's administrative requirements. In addition, a heavy work load environment on board detracts from the respirator program receiving more attention.	• Personnel difficulty • Operations problem • Training • Training LTA • Program design LTA • Personnel difficulty • Operations problem • Immediate supervision • Supervision during work • Supervision LTA • Human factors engineering • Workload • Unrealistic monitoring requirements	• Promulgate written Coast Guard instructions outlining the training necessary to administer a respirator program



Step 4 Determine the Risk Impact of Findings

***Risk impact of a finding** — the relative risk weighting of a finding representing the potential increase in unit risk because of the finding.*

The risk impact of safety survey findings provides a foundation for:

- Prioritizing findings for resolution
- Planning future surveys
- Trending the effectiveness of requirements
- Updating the coarse hazard analysis
- Updating the safety survey process

Finding	Evaluation Point (Checklist Item)	Affected Deviation (Operation/Evolution *Function* Deviation)	Baseline Frequency Scores A/B	Baseline Frequency Scores C	Baseline Frequency Scores D	RIN	Revised Frequency Scores A/B	Revised Frequency Scores C	Revised Frequency Scores D	Revised RIN	Change in RIN	Risk Impact
No record of preventive maintenance of lifting/lowering system	N014	**Small boat launch/recovery:** **From vessel** *Operating lifting equipment* Incorrect load position, direction, speed	2	3	4	0.009	3	5	6	0.63	0.621	
		Small boat launch/ recovery: **From vessel** *Operating lifting equipment* Loss of support	2	3	3	0.0063	3	4	5	0.09	0.0837	
	Risk Impact of Finding										0.70	Low
No sewage CHT operating instructions posted in the sewage space	I001	**Not operation/ evolution specific** *Providing sewage services* Biological/hazards exposure	3	3	4	0.036	3	4	5	0.09	0.054	
		Not operation/ evolution specific *Providing sewage services* Fire/explosion	4	4	5	0.36	4	5	6	0.9	0.54	
	Risk Impact of Finding										0.59	Low

Step 4.A Identify the coarse hazard analysis deviation(s) affected by the finding

Finding	Evaluation Point (Checklist Item)	Affected Deviation (Operation/Evolution *Function* Deviation)	Baseline Frequency Scores A/B	Baseline Frequency Scores C	Baseline Frequency Scores D	RIN	Revised Frequency Scores A/B	Revised Frequency Scores C	Revised Frequency Scores D	Revised RIN	Change in RIN	Risk Impact
No record of preventive maintenance of lifting/lowering system	N014	**Small boat launch/recovery: From vessel** *Operating lifting equipment* Incorrect load position, direction, speed	2	3	4	0.009						
		Small boat launch/ recovery: From vessel *Operating lifting equipment* Loss of support	2	3	3	0.0063						
	Risk Impact of Finding											
No sewage CHT operating instructions posted in the sewage space	I001	**Not operation/ evolution specific** *Providing sewage services* Biological/hazards exposure	3	3	4	0.036						
		Not operation/ evolution specific *Providing sewage services* Fire/explosion	4	4	5	0.36						
	Risk Impact of Finding											

Each safety survey finding is associated with a safety survey evaluation point (checklist item) and/or requirement. Each evaluation point or requirement has been correlated to one or more deviations in the coarse hazard analysis. By using the evaluation point/requirement-to-deviation relationship, a finding can be correlated to a deviation(s).

Step 4.B Estimate revised frequency scores for each deviation to reflect the existence of the deficiency and calculate revised RINs

Finding	Evaluation Point (Checklist Item)	Affected Deviation (Operation/Evolution *Function* Deviation)	Baseline Frequency Scores A/B	Baseline Frequency Scores C	Baseline Frequency Scores D	RIN	Revised Frequency Scores A/B	Revised Frequency Scores C	Revised Frequency Scores D	Revised RIN	Change in RIN	Risk Impact
No record of preventive maintenance of lifting/lowering system	N014	Small boat launch/recovery: From vessel *Operating lifting equipment* Incorrect load position, direction, speed	2	3	4	0.009	3	5	6	0.63		
		Small boat launch/recovery: From vessel *Operating lifting equipment* Loss of support	2	3	3	0.0063	3	4	5	0 09		
	Risk Impact of Finding											
No sewage CHT operating instructions posted in the sewage space	I001	Not operation/ evolution specific *Providing sewage services* Biological/hazards exposure	3	3	4	0.036	3	4	5	0 09		
		Not operation/ evolution specific *Providing sewage services* Fire/explosion	4	4	5	0.36	4	5	6	0 9		
	Risk Impact of Finding											

For each deviation, estimate new frequency scores that characterize current risks, given the existence of the deficiency. It may be necessary to review the coarse hazard analysis tables to understand which safeguards were assumed to be effective in controlling risk. Calculate a revised risk index number (RIN) using the new frequency scores.

IMPORTANT!

Care should be taken to ensure that the safeguard associated with the finding influenced the risk characterization in the coarse hazard analysis. The safeguard may have been known to be unreliable and therefore significant in the coarse hazard analysis. The frequency scores would already reflect the absence of this safeguard and would not be affected by the finding.

Note:
This equation is derived assuming an average Class A/B mishap is equivalent to $300,000, an average Class C mishap is equivalent to $30,000, and an average Class D mishap is equivalent to $3,000.

Calculate the RIN for each deviation by using the following equation:

$$RIN = (0.3 * 10^{(FsA/B)} + 0.03 * 10^{(FsC)} + 0.003 * 10^{(FsD)})/10{,}000$$

Where:

FsA/B = the frequency score for Class A/B mishaps
FsC = the frequency score for Class C mishaps
FsD = the frequency score for Class D mishaps

For a complete derivation of the RIN, see Section 5, Step 3.B.2.

Step 4.C Subtract the baseline RIN from the revised RIN

The change in RIN due to the finding provides a relative measure of the risk impact associated with the finding.

Finding	Evaluation Point (Checklist Item)	Affected Deviation (Operation/Evolution *Function* Deviation)	Baseline Frequency Scores			RIN	Revised Frequency Scores			Revised RIN	Change in RIN	Risk Impact
			A/B	C	D		A/B	C	D			
No record of preventive maintenance of lifting/lowering system	N014	**Small boat launch/recovery: From vessel** *Operating lifting equipment* Incorrect load position, direction, speed	2	3	4	0.009	3	5	6	0.63	0.621	
		Small boat launch/ recovery: From vessel *Operating lifting equipment* Loss of support	2	3	3	0.0063	3	4	5	0.09	0.0837	
	Risk Impact of Finding											
No sewage CHT operating instructions posted in the sewage space	I001	**Not operation/ evolution specific** *Providing sewage services* Biological/hazards exposure	3	3	4	0.036	3	4	5	0.09	0.054	
		Not operation/ evolution specific *Providing sewage services* Fire/explosion	4	4	5	0.36	4	5	6	0.9	0.54	
	Risk Impact of Finding											

Step 4.D Add the changes in RIN of all deviations associated with the finding and determine a risk impact for the finding

Use the change in RIN and the table below to assign a risk impact to each finding.

Risk Impact	Definition	Criteria*
High	Significant increase in overall vessel risk	Increase of RIN by more than 20
Medium	Moderate increase in overall vessel risk	Increase of RIN by more than 1, but less than 20
Low	Minor increase in overall vessel risk	Increase of RIN by more than 0.01, but less than 1
Very Low	Undesirable condition, but no significant change in vessel risk	Increase of RIN by less than 0.01

*Criteria based on the cumulative increase in risk index numbers for the relevant hazard analysis deviations

Finding	Evaluation Point (Checklist Item)	Affected Deviation (Operation/Evolution *Function* Deviation)	Baseline Frequency Scores			RIN	Revised Frequency Scores			Revised RIN	Change in RIN	Risk Impact
			A/B	C	D		A/B	C	D			
No record of preventive maintenance of lifting/lowering system	N014	**Small boat launch/recovery: From vessel** *Operating lifting equipment* Incorrect load position, direction, speed	2	3	4	0.009	3	5	6	0.63	0.621	
		Small boat launch/ recovery: From vessel *Operating lifting equipment* Loss of support	2	3	3	0.0063	3	4	5	0.09	0.0837	
	Risk Impact of Finding										0.70	Low
No sewage CHT operating instructions posted in the sewage space	I001	**Not operation/ evolution specific** *Providing sewage services* Biological/hazards exposure	3	3	4	0.036	3	4	5	0.09	0.054	
		Not operation/ evolution specific *Providing sewage services* Fire/explosion	4	4	5	0.36	4	5	6	0.9	0.54	
	Risk Impact of Finding										0.59	Low

Step 4.E Prioritize findings by risk impact category

One of the key results of making risk-based judgments is prioritizing the findings for resolution. Establishing a resolution order helps to efficiently and effectively use unit resources. The findings with higher risk impact are resolved first to ensure unit risk is managed appropriately. (Occasionally, findings with lower risk impact will require such a low level of resources to resolve that it makes sense to resolve them with the higher risk impact findings.)

Finding	Risk Impact Category
Gasoline was stored in a white plastic 5-gallon bucket and was slowly leaking on the deck	High
Water was leaking into the CIWS control room and was pooling on the floor	High
Crewmen in the paint locker were not wearing respirators and were not aware of the need to wear respirators	High
Walk-in refrigerator was not maintaining the appropriate temperature	Medium
No expiration date was listed on personal eyewash stations in the EM shop	Low
Top protective cover for the drill press in the maintenance shop was missing	Low
Battle lantern in the wardroom was not working	Very Low
Forward sewage did not have a sign posted saying: "No eating, drinking, or smoking in this space"	Very Low

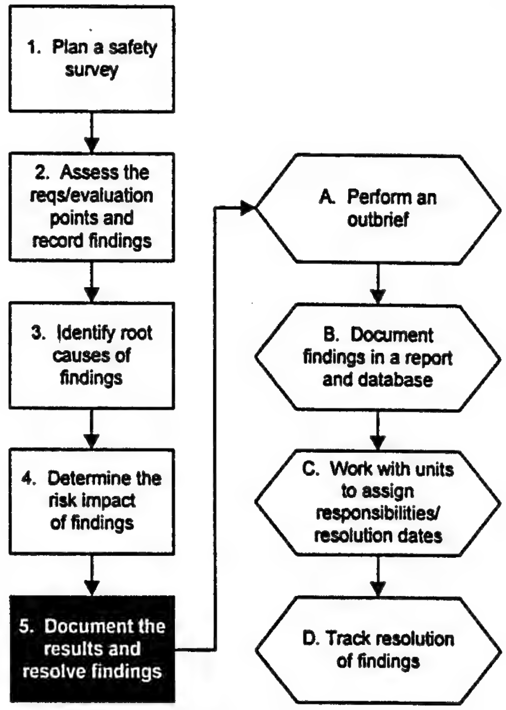
Note:
The order of resolving findings is ultimately left to the unit commands.

The prioritization of findings is designed to be a tool to help unit commands manage resources. Using the risk significance categories, the survey team suggests a resolution order.

Step 4.F Prioritize the findings within a risk impact category

This step is less critical than the previous step; however, it may be very worthwhile for a unit with a large number of findings in a single category. Typical criteria for prioritizing within a category include:

- Cost to resolve the finding
- Length of time required to resolve the finding
- Political implications of the finding
- Perceived risk of the finding relative to other findings in the category



Step 5. Document the Results and Resolve Findings

The results of the safety survey are presented in an outbrief and documented in a brief safety survey report. The findings are recorded in a findings database (e.g., Hazard Condition Notice [HCN] database).

Step 5.A Perform an outbrief

The survey visit should be concluded with an outbrief. The purpose of an outbrief is to give the unit command immediate feedback from the survey and to discuss the remaining steps of the safety survey process. As with the inbrief, the Coast Guard is very experienced at performing outbriefs and, therefore, the method for performing an outbrief will be left to the discretion of individual survey teams. However, consider including these topics:

- The survey team's impression of the severity of the findings (general state of the unit)
- A preliminary list of the significant findings
- The preliminary root causes
- The next steps in the safety survey process (i.e., root cause analysis, risk impact of findings, prioritizing findings, and safety survey report)
- A schedule for when the safety survey report will be finished and submitted to the unit
- A discussion on the contents of the safety survey report

Step 5.B Document findings in a report and database

Safety survey report

Shortly after the safety survey, a brief written report documenting the safety survey results should be presented to the unit command. The report should include the following information:

- Prioritized list of findings with a suggested order to resolve the findings
- Explanation of the findings, including number of instances and unit location
- Root causes of the findings
- Global implications of the findings
- Any additional information the survey team sees fit to convey

Findings database

The survey team should document the findings in a findings database (e.g., HCN database). For example, the following information could be recorded about each finding:

- Unit class and unit
- Date of finding
- Associated requirement/evaluation point
- Risk impact category of finding
- Individual responsible for resolution of finding
- Target resolution date

Step 5.C Work with unit commands to assign responsibilities and target resolution dates

It is up to unit commands to resolve the findings in a timely manner; however, the survey team plays an integral part in the resolution.

Different unit commands may choose to assign responsibilities and target resolution dates in various ways. It is typically out of the survey team's control to make assignments. However, the survey team can suggest guidelines for establishing target resolution dates such as in the table below.

Risk Impact	Guidance[1]
High[2]	Resolve at earliest convenient time within a 1-month period
Medium	Resolve at earliest convenient time within a 6-month period
Low	Resolve at earliest convenient time within a 12-month period
Very Low	Resolve at earliest convenient time before the next safety survey

[1] Items may be resolved by permanent corrective actions or temporary mitigative actions until a more permanent action can be implemented.

[2] Some items may require immediate attention before (or shortly after) the safety survey ends.

Step 5.D Track resolution of findings

The survey team should work with the unit command to track the findings until resolution.

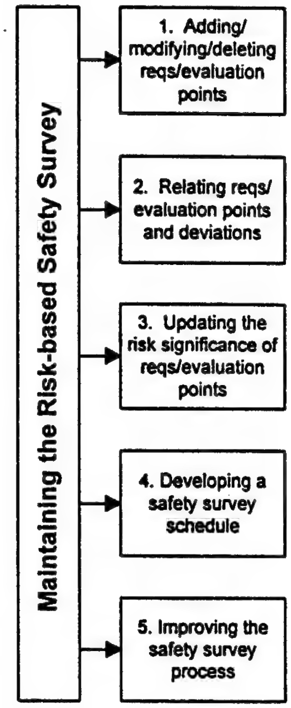
Finding #	Finding	Planned Resolution	Risk Impact	Target Resolution Date	Status	Completed Date
F001	No record of preventive maintenance of hoses and disconnects	Perform maintenance Develop preventive maintenance plan for hoses and disconnects	Low	4/13/97 4/27/97	Maintenance performed Writing plan	5/4/97
F002	No sewage CHT operating instructions posted in the sewage space	Post instructions	Low	4/2/97	Instructions posted	4/2/97

The IRA Risk-based Safety Survey

- Introduction
- Performing a risk-based safety survey
- Maintaining the risk-based safety survey process
- Information exchange between the risk-based safety survey and the coarse hazard analysis
- Using the risk-based safety survey to update the coarse hazard analysis
- Making decisions using the IRA risk-based safety survey

Maintaining the Risk-based Safety Survey Process

Several maintenance activities must be performed on the safety survey process to ensure that the process is continually improving and remains effective as unit risks change. As the safety survey process matures, the survey results are used to continually improve the effectiveness of the process. The process relies on historical safety survey information to improve the accuracy of measures of risk and risk rankings. Also, Coast Guard unit configurations, operations, and personnel are continuously being changed (e.g., the addition of a waste incinerator, new limitations on boarding operations, reduction in force on a class of cutters); each of these changes affects unit risk. The safety survey must be adaptive to change to effectively manage unit risk.



Overview of the Activities for Maintaining the Risk-based Safety Survey Process

This section outlines the activities for maintaining the risk-based safety survey process.

1. **Adding/modifying/deleting requirements/evaluation points**

   Often it is necessary to add/modify/delete requirements/evaluation points to improve the results of the safety survey process and to ensure that issues with high risk significance are effectively surveyed.

2. **Updating relationships between requirements/evaluation points and deviations**

   The key to determining the risk significance of evaluation points is the relationship between evaluation points and coarse hazard analysis deviations. Each requirement/evaluation point should be associated with one or more deviations.

3. **Updating the risk significance of requirements/evaluation points**

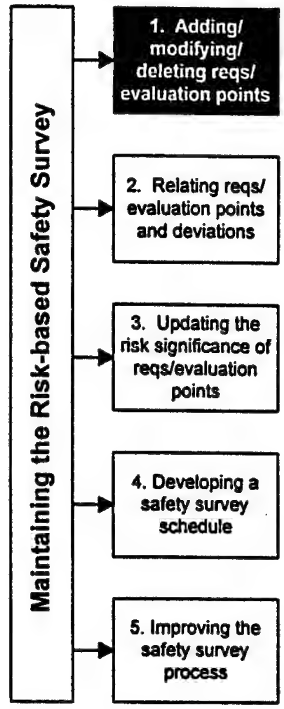
   The risk significance of the requirements/evaluation points helps to plan a safety survey in which resources are efficiently and effectively used.

4. **Developing a safety survey schedule**

   A safety survey schedule provides a systematic means to assess requirements/evaluation points proportional to their associated risk significance while ensuring that all requirements/evaluation points are assessed over a period of time.

5. **Improving the safety survey process**

   Continually improving the process as it matures will help it run more smoothly and be more effective in controlling risk.



Step 1 Adding/Modifying/Deleting Requirements/Evaluation Points

Occasionally, it will be necessary to add, modify, or delete a requirement/evaluation point. The following are five typical reasons for making changes to the set of safety survey requirements/evaluation points.

Due to hazard analysis (coarse and detailed) recommendations

Hazard analysis results may reveal the need for additional safeguards to manage risk due to a change in unit configuration, operation, or personnel. These safeguards may require (whether regulatory driven or Coast Guard management driven) evaluation points to assess their effectiveness. Also, a low risk characterization coupled with a lack of survey findings may suggest that an evaluation point is not needed for a particular issue and the evaluation point could be deleted.

Due to regulatory requirements

The addition/modification/deletion of Coast Guard regulatory requirements will change the set of requirements/evaluation points in a safety survey.

Due to MISREP/CASREP data

Historical MISREP/CASREP (mishaps) data may reveal the need for additional requirements (safeguards) to prevent or mitigate mishaps. Evaluation points will be developed to ensure the implementation of the requirements. Also, MISREP/CASREP data may reveal the need for a modification to requirements/evaluation points to prevent or mitigate mishaps.

Due to safety surveys

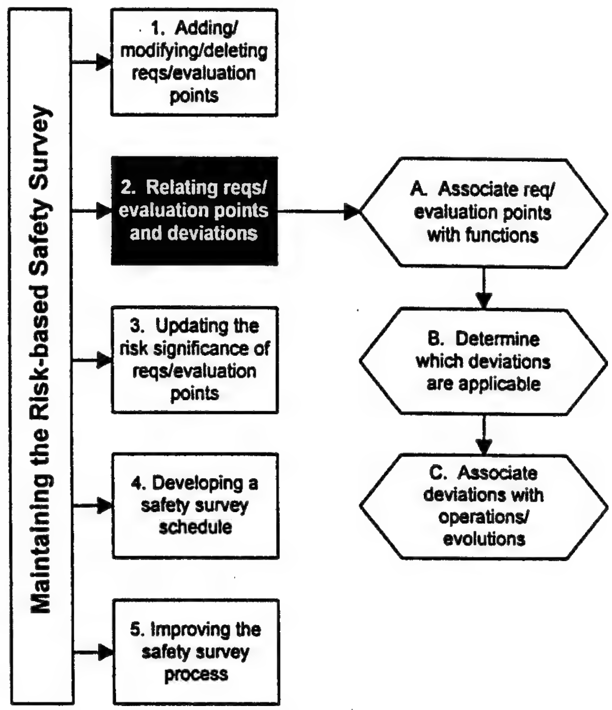
During the safety survey (and from the results), the survey team may believe that evaluation points are not stated accurately enough to thoroughly assess the critical issues or an evaluation point(s) may be missing for a critical issue(s). The survey team should work to improve the survey by adding or modifying requirements/evaluation points. Also, the lack of survey findings coupled with a low risk characterization from the hazard analysis may suggest that an evaluation point is not needed for a particular issue and the evaluation point could be deleted.

Due to unit command or Coast Guard management

Unit commands or Coast Guard management may decide that certain issues warrant additional evaluation points. The following are reasons they may have for adding evaluation points:

- An unacceptable number of findings or mishaps surrounding an issue (at the unit or other units)
- Inexperience of unit personnel with a certain issue (e.g., type of hardware, type of chemical, unit operation)
- Change in unit configuration, operation, or personnel

Note:
Often, a requirement has not changed but an evaluation point may need to be reworded to improve its effectiveness in assessing the requirement.



Step 2 Relating Requirements/Evaluation Points and Deviations

All requirements/evaluation points should be correlated to one or more coarse hazard analysis deviations. This correlation provides the means to risk rank the requirements/evaluation points, risk rank survey findings, and update the coarse hazard analysis using the safety survey results.

Step 2.A Associate requirements/evaluation points with unit functions

Requirement	Evaluation Point	Vessel Function
COMDTINST M9000.6B	Is a thorough davit and boat hoist installation inspection conducted annually in conjunction with the boat hull inspection, and are the results recorded in the cutter's hull history?	*Operating lifting equipment*
COMDTINST M9000.6B	Have helicopter deck tie-down fittings been given a certified pull test, and are records available upon request and recorded in the hull history log?	*Operating lifting equipment*
NSTM 583.7.5	Are slings designed for a specific boat only used to lift that type of boat?	*Operating lifting equipment*
NSTM 583.7.5	Are slings taken out of service when signs of deterioration are noted?	*Operating lifting equipment*

Step 2.B Determine which deviation(s) within the function is applicable to the requirement

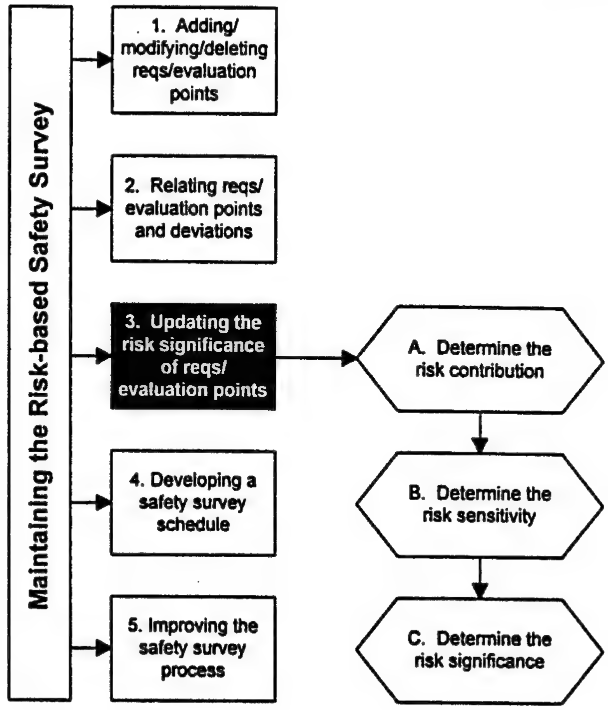
Requirement	Evaluation Point	Vessel Function	Deviation
COMDTINST M9000.6B	Is a thorough davit and boat hoist installation inspection conducted annually in conjunction with the boat hull inspection, and are the results recorded in the cutter's hull history?	*Operating lifting equipment*	Loss of support
COMDTINST M9000.6B	Have the helicopter deck tie-down fittings been given a certified pull test, and are records available upon request and recorded in the hull history log?	*Operating lifting equipment*	Loss of support
NSTM 583.7.5	Are slings designed for a specific boat only used to lift that type of boat?	*Operating lifting equipment*	Loss of support
NSTM 583.7.5	Are slings taken out of service when signs of deterioration are noted?	*Operating lifting equipment*	Loss of support

Note:
This provides a correlation that will be refined in the next step. The deviation must also be associated with one or more operations/evolutions.

Step 2.C Eliminate the requirements that do not apply to the deviation when the deviation is associated with an operation/evolution

Operation/ Evolution	Vessel Function	Deviation	Requirement	Evaluation Point
Small boat launch/recovery from vessel	*Operating lifting equipment*	Loss of support	COMDTINST M9000.6B	Is a thorough davit and boat hoist installation inspection conducted annually in conjunction with the boat hull inspection, and are the results recorded in the cutter's hull history?
	~~*Operating lifting equipment*~~	~~Loss of support~~	~~COMDTINST M9000.6B~~	~~Have the helicopter deck tie-down fittings been given a certified pull test, and are records available upon request and recorded in the hull history log?~~
	Operating lifting equipment	Loss of support	NSTM 583.7.5	Are slings designed for a specific boat only used to lift that type of boat?
	Operating lifting equipment	Loss of support	NSTM 583.7.5	Are slings taken out of service when signs of deterioration are noted?

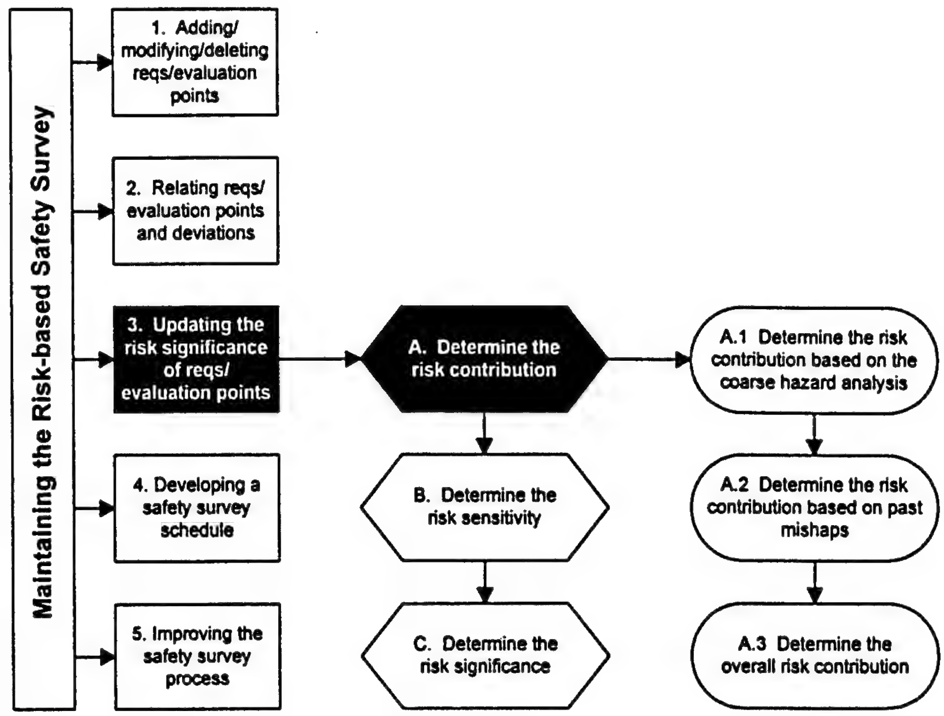
Note:
*Remember that a deviation within the coarse hazard analysis is defined by its associated function and operation/evolution. A requirement that may apply to a deviation during **towing** may **not** apply to the same deviation during **helicopter operations**.*



Step 3

Updating the Risk Significance of Requirements/ Evaluation Points

Risk ranking requirements/evaluation points provides a means for planning a safety survey. Requirements/evaluation points are risk ranked using a relative measure of risk called risk significance. The risk significance is determined by calculating the risk contribution and risk sensitivity of the requirement/evaluation point. The requirements/evaluation points are risk ranked by their risk significance. This risk ranking ensures that safety survey efforts are only reduced for those evaluation points that have both (1) a low risk contribution and (2) a low risk sensitivity. The following sections explain the processes required to determine risk contribution, risk sensitivity, and risk significance.



Step 3.A Determine the risk contribution

***Risk contribution** — the fraction of total unit risk for which deficiencies associated with a requirement/evaluation point are contributors*

Risk contribution of a requirement/evaluation point is determined based on (1) coarse hazard analysis results and (2) investigation of past mishaps.

Note:
Both means should be used to determine risk contribution. However, if there is a lack of information, using only one means is acceptable.

Steps to determine the risk contribution

3.A.1 Determine the risk contribution based on the coarse hazard analysis
3.A.2 Determine the risk contribution based on past mishaps
3.A.3 Determine the overall risk contribution

Step 3.A.1 Determine the risk contribution based on coarse hazard analysis results

Identify the deviations associated with a requirement/evaluation point and sum the risk contribution of the deviations.

Requirement	Evaluation Point	Deviation (Operation/Evolution *Function* Deviation)	Risk Contribution
NSTM 5533-2.1.3	G002	Not operation/evolution specific *Providing potable water services* Potable water quality problems	0.052
Total Risk Contribution			**0.052**
COMDTINST M6240.4A, Ch. 3-F-1 thru 3-F-3 and 12-A	H043	Not operation/evolution specific *Providing food services* Inadequate/no food service	0.0005
		Not operation/evolution specific *Providing food services* Food quality problem	0.0005
		Not operation/evolution specific *Providing food services* Biological hazards exposure	0.0005
Total Risk Contribution			**0.0015**

Using the following table, determine the risk contribution importance based on coarse hazard analysis results.

Risk Contribution Importance	Description
High	Requirement/evaluation point with risk contribution ≥ 0.1
Medium	Requirement/evaluation point with risk contribution ≥ 0.01 and <0.1
Low	Requirement/evaluation point with risk contribution <0.01

Example

- Risk contribution importance of G002 = Medium
- Risk contribution importance of H043 = Low

Step 3.A.2 **Determine the risk contribution of a requirement/evaluation point based on past mishaps**

Identify the mishaps associated with a requirement/evaluation point.

Requirement	Evaluation Point	Actual Mishap	Date	Mishap Category
NSTM 553-2.13	G002	Seaman used the potable water hose to pump water from the bilge. Potable water hose was replaced	3/14/95	D
		Seaman used wrong hose to replenish the potable water system. Subsequently, 13 seaman were admitted to the hospital for illness	11/3/93	A/B
COMDTINST M6240.4A, Ch. 3-F1 thru 3-F-3 and 12-A	H043	Food service personnel improperly stored a shipment of beef. Subsequently, the entire shipment spoiled and was thrown out	6/28/95	C

Calculate the risk contribution.

$$\frac{\sum \text{A / B Events}_{\text{Evaluation point as contributor}} \times 100 + \sum \text{C Events}_{\text{Evaluation point as contributor}} \times 10 + \sum \text{D Events}_{\text{Evaluation point as contributor}}}{\sum \text{A / B Events}_{\text{Total}} \times 100 + \sum \text{C Events}_{\text{Total}} \times 10 + \sum \text{D Events}_{\text{Total}}}$$

Example

- Total A/B events = 5
- Total C events = 7
- Total D events = 23

Risk contribution of G002 based on past mishaps
((1 x 100) + (0 x 10) + 1)/593 = 0.17
Risk contribution of H043 based on past mishaps
((0 x 100) + (1 x 10) + 0)/593 = 0.017

Using the following table, determine the risk contribution importance based on past mishaps.

Risk Contribution Importance	Description
High	Requirement/evaluation point with risk contribution ≥ 0.1
Medium	Requirement/evaluation point with risk contribution ≥ 0.01 and <0.1
Low	Requirement/evaluation point with risk contribution <0.01

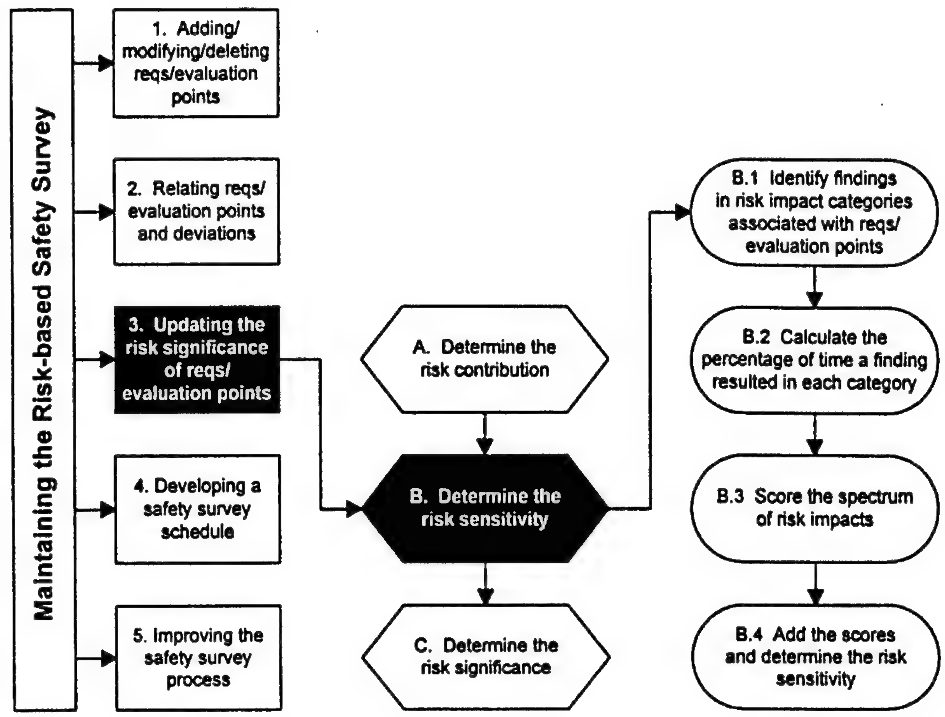
Example

- Risk contribution importance of G002 = High
- Risk contribution importance of H043 = Medium

Step 3.A.3 Determine the overall risk contribution of a requirement/evaluation point

Evaluation Point	Risk Contribution Based on Coarse Hazard Analysis	Risk Contribution Based on Past Mishaps	Risk Contribution
G002	Medium	High	High
H043	Low	Medium	Medium

The overall risk contribution is the highest level of importance identified based on coarse hazard analysis results and past mishaps. As demonstrated in the table, evaluation point G002 has a coarse hazard analysis-based risk contribution of Medium and a past mishap-based risk contribution of High. Thus, G002's risk contribution is **High**.



Step 3.B Determine the risk sensitivity

***Risk sensitivity** — the change in total unit risk with a change in the dependability of a safeguard (requirement/evaluation point)*

Risk sensitivity analysis of a requirement/evaluation point (safeguard) is necessary due to the inherent uncertainty in determining risk contribution. Risk sensitivity is a relative measure of the impact that the degradation of a safeguard (requirement/evaluation point) has on total unit risk. Risk sensitivity provides insight into how risk contribution might change if a safeguard were a little more, or a little less, dependable than estimated in the coarse hazard analysis. If the safeguard reliability information used to determine the risk associated with a deviation was 100% accurate, there would be no need for risk sensitivity analysis.

The analysis assigns a risk sensitivity (High, Medium, or Low) to a requirement/evaluation point by observing the types of findings associated with the requirement/evaluation point over time. A requirement/evaluation point that produces High or Medium findings the majority of the time will most likely have a High risk sensitivity. Risk sensitivity is used with risk contribution to determine overall risk significance.

Steps to determine the risk sensitivity

3.B.1 Identify findings in risk impact categories associated with requirements/evaluation points

3.B.2 Calculate the percentage of time a finding resulted in each category

3.B.3 Score the spectrum of risk impacts

3.B.4 Add the scores and determine the risk sensitivity

Step 3.B.1 Identify the number of findings in each risk impact category

Requirement	Evaluation Point	The Number of Findings in Each Risk Impact Category			
		Very Low	Low	Medium	High
NSTM 553-2.1.3	G002	2	0	2	5
COMDTINST M6240.4A, Ch. 3-F-1 thru 3-F-3 and 12-A	H043	6	2	1	0

Step 3.B.2 Calculate the percentage of time a finding associated with a requirement/evaluation point resulted in each risk impact category

Requirement	Evaluation Point	Percentage of Time a Finding Associated with a Requirement/Evaluation Point Resulted in Each Risk Impact Category			
		Very Low	Low	Medium	High
NSTM 553-2.1.3	G002	22%	0%	22%	56%
COMDTINST M6240.4A, Ch. 3-F-1 thru 3-F-3 and 12-A	H043	66%	22%	11%	0%

Example

From the table in Step 1, there have been a total of nine findings recorded for G002. The percentages in the table above are calculated by dividing the number of findings in a category by the total number of findings. The percentages for G002 are calculated as follows:

Very Low	2/9 = 0.22	22%
Low	0/9 = 0	0%
Medium	2/9 = 0.22	22%
High	5/9 = 0.56	56%

Step 3.B.3 **Score the spectrum of risk impacts for each requirement/ evaluation point**

Use the percentages from Step 2 to identify a score for each risk impact category using the table below.

Percentage of Time that the Findings Associated with a Requirement/ Evaluation Point Resulted in the Listed Risk Impact Categories	Risk Impact Score for Categories of Findings			
	Very Low	Low	Medium	High
80% to 100%	0.01*	1	20	50
10% to 80%	0	0.8	16	40
>0% to 10%	0	0.1	2	5
0%	0	0	0	0

* Scores (relative weights) used for assessing risk sensitivity of requirement/evaluation points

Example

For G002,

Very Low 0
Low 0
Medium 16
High 40

Step 3.B.4 Add the scores and determine the risk sensitivity

$$Score_{Sensitivity} = Score_{Very\ low} + Score_{Low} + Score_{Medium} + Score_{High}$$

Method for Categorizing Risk Sensitivity of Requirements/Evaluation Points	
Risk Sensitivity	**Description**
High	Requirements/evaluation points with a risk sensitivity score of ≥ 20
Medium	Requirements/evaluation points with a risk sensitivity score of ≥ 1 and > 20
Low	Requirements/evaluation points with a risk sensitivity score of < 1

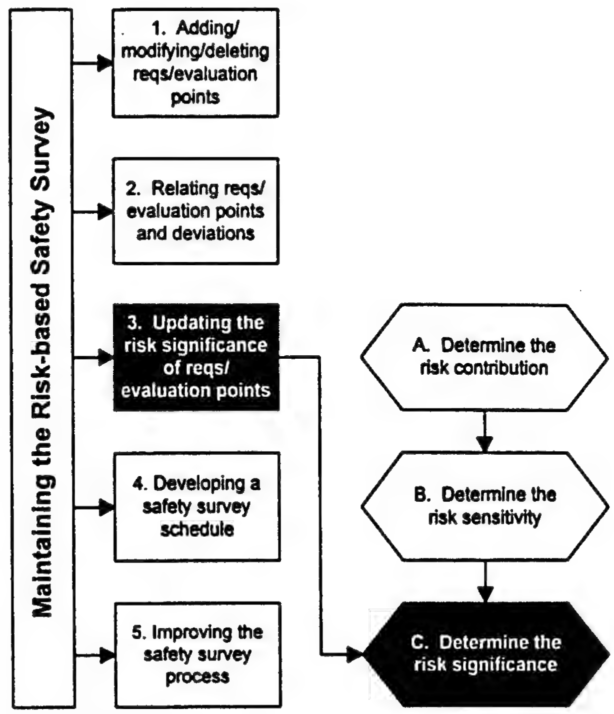
Example

For G002

$Score_{Risk\ Sensitivity} = 0 + 0 + 16 + 40$

$Score_{Risk\ Sensitivity} = 56$

Using the table above, risk sensitivity of G002 is High.



Step 3.C Determine the risk significance

***Risk significance of a requirement/evaluation point** — a weighting of each requirement/evaluation point based on multiple measures of risk importance.*

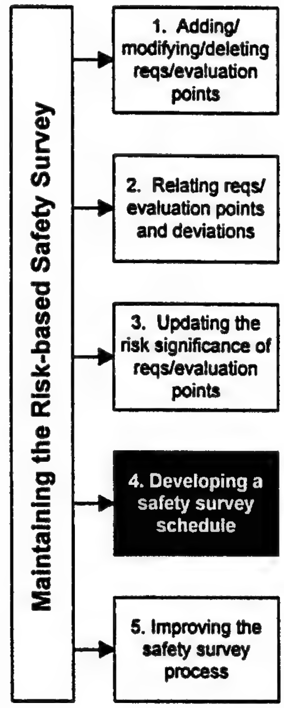
Risk significance is a function of risk *contribution* and risk *sensitivity*.

Risk significance of requirements/evaluation points is based on risk contribution and is assigned as High, Medium, or Low. If risk sensitivity is low, the risk significance is the same as the risk contribution. However, when risk sensitivity is greater, adjustments to the risk contribution ratings are made (as shown in the table below) to assign risk significance.

Risk Sensitivity Importance	Increase in Contribution-based Importance to Establish the Risk Significance of Evaluation Points
High	Two categories (e.g., Low risk contribution becomes High risk significance)
Medium	One categories (e.g., Low risk contribution becomes Medium risk significance)
Low	No change (e.g., Low risk contribution becomes Low risk significance)

Example

Requirement/ Evaluation Point	Risk Importance		Risk Significance
	Risk Contribution	Risk Sensitivity	
G002	High	High	High
H043	Medium	Medium	High



Step 4 Developing a Safety Survey Schedule

The goal of developing a risk-based safety survey schedule is to maintain appropriate control of risk while using limited survey resources most efficiently. Fewer resources means it will be difficult to assess the growing number of requirements/evaluation points during each safety survey. The solution is to reduce the set of evaluation points reviewed during a survey by reviewing evaluation points at a frequency proportional to their risk significance. This is accomplished by developing different survey intensities or safety survey levels, as shown in the table below, and applying a different survey level each time a vessel is surveyed.

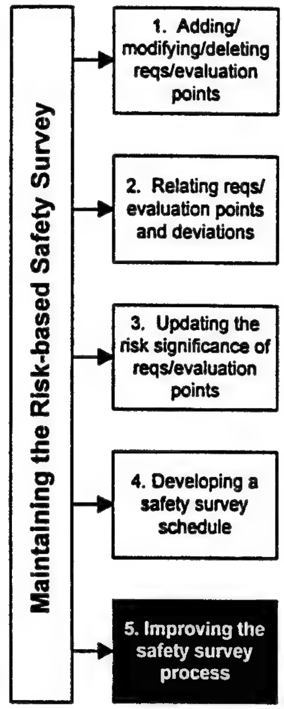
Survey Level	Description
1	Assess in detail all evaluation points (within subject matter scope) listed as High, Medium, or Low risk significance
2	Assess in detail all evaluation points (within subject matter scope) listed as Medium or High risk significance
3	Assess in detail all evaluation points (within subject matter scope) listed as High risk significance

Note:
When planning the safety survey, it is important to be flexible and include requirements/evaluation points or issues that warrant attention, but are not included in the safety survey level that is scheduled

These survey levels are incorporated into a schedule such as the one below. The schedule below is on a 3-year cycle.

Coast Guard Asset	Year 1	Year 2	Year 3	Year 4	etc...
Vessel Class 1	Level 1	Level 2	Level 3	Level 1	
Vessel Class 2	Level 3	Level 1	Level 2	Level 3	
etc...					

The different levels of a safety survey and a schedule such as the one above assesses high risk issues (requirements/evaluation points) on a regular basis (every time a survey is performed), medium risk issues on a less frequent basis (fewer review cycles), and low risk issues on an even less frequent basis.



Step 5 Improving the Safety Survey Process

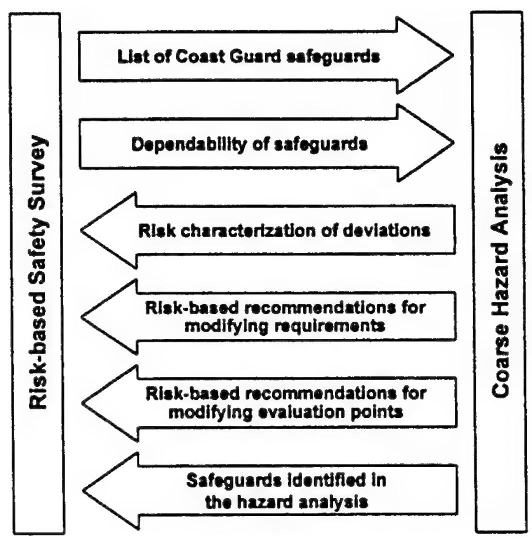
The mechanics and performance of the safety survey process should continually improve as it matures. Safety survey teams should continually look for ways to tweak the process to make it run more smoothly and be more effective in managing risk. The following are several ways survey teams can strive to improve the process:

- Look for ways to have less of an impact on a unit during a survey, but still remain effective
- Review the survey activities and results after a survey is performed, brainstorm ways to improve the effectiveness of the survey, implement the ideas on the next survey, and compare the results
- Ask unit personnel about the perceived benefits and drawbacks of the safety survey process
- Look for improvements in the wording of evaluation points to make them clear and effective in assessing the intent of the associated requirement(s)

The IRA Risk-based Safety Survey

- Introduction
- Performing a risk-based safety survey
- Maintaining the risk-based safety survey process
- Information exchange between the risk-based safety survey and the coarse hazard analysis
- Using the risk-based safety survey to update the coarse hazard analysis
- Making decisions using the IRA risk-based safety survey

Information Exchange Between the Risk-based Safety Survey and the Coarse Hazard Analysis



Risk-based Safety Survey ⇨ Coarse Hazard Analysis

1. *List of Coast Guard safeguards*

   The requirements within the safety surveys define how the Coast Guard will implement safeguards to prevent mishaps. These requirements and safeguards provide the bases for coarse hazard analysis teams to judge whether the risk of possible deviations is acceptable.

2. *Information about the dependability of safeguards*

   Summaries of frequencies/severities of nonconformances from Coast Guard requirements during past surveys help hazard analysis teams judge the dependability of safeguards in preventing mishaps.

Coarse Hazard Analysis ⇨ Risk-based Safety Survey

1. *Risk characterization of deviations*

   The safety survey process uses the risk characterization of deviations to characterize survey findings. By trending findings, the dependability of safeguards can be analyzed. It may be necessary to adjust the risk scores associated with certain deviations to reflect the historical safeguard information from the safety surveys.

2. *Risk-based recommendations for adding/modifying/deleting requirements or evaluation points*

   While evaluating possible deviations that may lead to mishaps, coarse hazard analysis teams may identify that a Coast Guard requirement should be (1) added to provide an additional safeguard or to make an existing safeguard more effective, (2) modified to make an existing safeguard more effective or its implementation less burdensome, and/or (3) eliminated because of marginal (or no) benefit.

3. *Required safeguards identified during the coarse hazard analysis*

   The coarse hazard analysis identifies safeguards necessary to achieve an acceptable level of risk. Requirements and evaluation points ensure that these safeguards are effectively performing their design intent. Evaluation points may be needed to assess important safeguards that are not even actual requirements (and, therefore, are not currently in evaluation point checklists).

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Using the Risk-based Safety Survey to Update the Coarse Hazard Analysis

The safety survey process can assist in updating the deviation risk scores in the coarse hazard analysis under two circumstances: (1) during a periodic coarse hazard analysis update and (2) when historical safety survey data provide evidence that the risk score of a deviation should be reviewed.

Regardless of the circumstance, the method used is the same. The safety survey process catalogs information about past deficiencies and provides insight into the dependability of various loss prevention safeguards over a period of time. Occasionally, it is necessary to reevaluate the risk characterizations of deviations in the coarse hazard analysis because the safeguards are less dependable than was thought during the analysis.

Findings with high risk impacts indicate how undependable a safeguard (requirement/evaluation point) has become. The coarse hazard analysis assumed that safeguards met their design intent and were reasonably dependable.

Findings data can be used to identify deviations requiring review by analyzing the percentage of time a finding associated with a requirement/evaluation point results in each risk impact category.

Requirement	Evaluation Point	Percentage of Time a Finding Associated with a Requirement/Evaluation Point Resulted in Each Risk Impact Category			
		Very Low	Low	Medium	High
NSTM 553-2.1.3	G002	8%	0%	8%	20%
COMDTINST M6240.4A, Ch. 3-F-1 thru 3-F-3 and 12-A	H043	40%	13%	6%	0%

The percentages are calculated by dividing the number of findings in each risk impact category by the total number of times an evaluation point is surveyed.

Example

Evaluation point G002 has been surveyed 25 times. Findings are as follows:

Very low	=	2
Low	=	0
Medium	=	2
High	=	5

Percentages for G002 are calculated as follows:

Very low	=	2/25	=	0.08	8%
Low	=	0/25	=	0	0%
Medium	=	2/25	=	0.08	8%
High	=	5/25	=	0.2	20%

This information may indicate the need to update the risk profiles in the coarse hazard analysis or could be used when periodically updating the coarse hazard analysis.

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Making Decisions Using the IRA Risk-based Safety Survey

The IRA risk-based safety survey results allow decision makers to incorporate risk-based information into the Coast Guard decision-making process. This section describes the ways Coast Guard decision makers use the hazard analysis results.

The following Coast Guard decision makers use these results:

- Engineering managers
- Facilities managers
- Unit commands
- Unit safety managers
- Senior management

Hazard analysis results are used in the following Coast Guard activities:

- Unit operations and maintenance
- Area, district, or group management of operations and maintenance
- Decommissioning

Only the activities that are applicable to a specific decision maker are listed. For each activity, a table provides typical uses of the risk-based safety survey that support the activity, example outcomes from using the safety survey, and the applicable safety survey results required to achieve the outcome.

Type of Activity	Decision Maker	Use of the Safety Survey Results	Example Outcome	Applicable Safety Survey Results
Vessel Operations and Maintenance	Engineering Managers Facilities Managers Vessel Commands Vessel Safety Managers	Identification of weaknesses in procedures that could lead to losses of interest (case-by-case basis for procedures developed and approved by vessel-board personnel)	Revising vague steps of a procedure (e.g., "open the valve slightly"), because a human error associated with the operation could lead to a loss of interest	Root cause analysis of findings
Area, District, or Group Management of Operations and Maintenance	Engineering Managers Facilities Managers Vessel Safety Managers Senior Management	Identification of design weaknesses, safe operating limits, critical preventive maintenance tasks, human factors issues, etc., for selected systems (i.e., those that could lead to losses of interest) aboard existing ships that did not receive such reviews before being placed in operation	1. Recommendations for side-scanning sonar to detect submerged objects for cutters traveling around reefs 2. Recommending redesign of a small craft launching system component that could inadvertently trigger a release of a boat	Root cause analysis of findings
		Identification of safe operating limits (from an operations/ command perspective rather than a hardware system design perspective, which was addressed during design reviews) and preferred precautions to be taken if operating outside of such restrictions	Prohibiting aircraft fueling operations and other flammable material handling activities until disabled onboard firefighting systems are returned to service, but allowing emergency fueling operations if another onboard pump can be rigged to temporarily provide adequate firefighting capability	Root cause analysis of findings
		Identification of critical training topics, necessary standard procedures, etc., for preventing losses of interest	Deciding to write a special procedure and conduct special training for the proper way to launch a new type of small craft (because the operation is significantly different from similar operations with older small craft)	Root cause analysis of findings
		Identification of weaknesses in procedures and human factors issues that could lead to losses of interest (for standard procedures applicable to a class of vessels or the entire fleet)	Making the units of pressure referenced in a procedure (e.g., SI units) consistent with those commonly used aboard a vessel and on the vessel's gauges (e.g., English units) to help prevent confusion that could lead to an operating error	Root cause analysis of findings

Type of Activity	Decision Maker	Use of the Safety Survey Results	Example Outcomes	Applicable Safety Survey Results
Area, District, or Group Management of Operations and Maintenance (continued)	Engineering Managers Facilities Managers Vessel Safety Managers Senior Management	Assigning measures of importance to safety inspection items to help prioritize responses to noted deficiencies	Deferring resolution of a few deficiencies noted during a safety inspection until next fiscal year because the deficiencies do not pose any significant risks of losses	1. Risk ranking of requirements/evaluation points 2. Risk ranking of findings associated with the issue
Decommissioning	Facilities Managers Senior Management	Identification of weaknesses in equipment used for decommissioning and associated procedures that could lead to losses of interest	Modifying the equipment and procedures used to de-inventory hazardous materials from a vessel while the vessel is being decommissioned	Root cause analysis of findings

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Section 9
Operations/Evolutions, Functions, and Deviations

Section 9 contains the following information:

1. **Operations/Evolutions** — The current list of Coast Guard operations/evolutions for vessels and shore facilities
2. **Functions and Deviations** — The current list of Coast Guard functions and deviations for vessels and shore facilities
3. **Guide to Functions** — A table of example activities that are within the scope and outside the scope of each function
4. **Guide to Deviations** — A table providing the purpose of each deviation and example issues related to each deviation
5. **Example Operation/Evolution and Function Matrices** — Example matrices for vessel, Integrated Support Command (ISC), and Marine Safety Office (MSO)

1. Operations/Evolutions — 1/1/98

Vessel

The operations/evolutions listed below constitute the complete set of operations/evolutions for all Coast Guard vessels. The operations/evolutions applicable to a specific vessel will depend on the vessel type and its mission(s).

- **Working aids to navigation**
- **Towing**
- **Boarding**
- **Damage control — fire**
- **Damage control — flood**
- **Helicopter operations**
- **Fueling — pier side**
- **Fueling — underway replenishment**
- **Small boat launch/recovery — from vessel**
- **Small boat launch/recovery — from land**
- **Anchored/moored/stored**
- **Vessel leaving/returning**
- **Vessel in transit/restricted waters**
- **Launch/recover swimmers/divers**
- **Not operation/evolution specific (includes open-water maneuvering)**

Shore — ISC

The operations/evolutions listed below constitute the complete set of operations/evolutions for all Coast Guard ISC operations. The operations/evolutions applicable to a specific ISC will depend on its mission(s).

- **Pier services**
- **Industrial services**
- **Base services**

Shore — MSO

The operations/evolutions listed below constitute *a sample* set of operations/evolutions for Coast Guard MSO operations. The operations/evolutions applicable to a specific MSO will depend on its mission(s).

- **Letter of Compliance inspections**
- **Overseas inspections**
- **Deep draft inspections — dry dock**
- **Pollution response (active and passive)**
- **Barge inspections**
- **Container inspections**
- **Waterfront facility inspections**
- **Port security operations**

2. Functions and Deviations — 1/1/98

The functions and deviations listed below are applicable to vessels and shore facilities unless otherwise indicated (e.g., ISC only, MSO and ISC only)

Note: The set of deviations in bold type under the first function are the standard set of deviations applicable to all functions.

Operating vessels/craft

- Vessel/craft unavailable
- Incorrect position/direction/speed
- Vessel/craft fails to maintain position
- Vessel struck by floating object
- Vessel impacts submerged object
- Vessel struck by another vessel
- **Physical hazards exposure**
- **Toxic/corrosive/reactive materials exposure**
- **Fire/explosion**
- **Asphyxiant environment exposure**
- **Electrical hazards exposure**
- **High pressure materials exposure**
- **High noise exposure**
- **Excessive vibration exposure**
- **Radiation exposure**
- **Biological hazards exposure**
- **Hot/cold environments exposure**
- **Hot/cold surfaces/materials exposure**

***Operating aircraft (in-flight and ground operations)*;** **vessel and MSO only**

- Aircraft unavailable
- Incorrect position/direction/power/speed
- Aircraft fails to maintain position
- **Standard set of deviations (listed under vessels/craft)**

***Operating powered vehicles (trucks, cars, mobile cranes, forklifts, etc.)*;** **ISC and MSO only**

- Vehicle unavailable
- Incorrect position/direction/speed
- Vehicle fails to maintain position
- **Standard set of deviations (listed under vessels/craft)**

Operating hand-operated moving equipment (dollies, carts, etc.)
- Equipment unavailable
- Incorrect position/direction/power/speed
- Equipment fails to maintain position
- **Standard set of deviations (listed under vessels/craft)**

Operating lifting equipment
- Lifting equipment unavailable
- Loss of support
- Incorrect load position/direction/speed
- **Standard set of deviations (listed under vessels/craft)**

Operating deck equipment (excluding small boat davit/crane); **vessel only**
- Deck equipment unavailable
- Loss of line support
- Incorrect direction/speed
- **Standard set of deviations (listed under vessels/craft)**

Providing/maintaining structures (buildings, piers, vessels, craft); **ISC and vessel only**
- Excessive static structural loading
- Excessive dynamic structural loading
- Structural degradation
- **Standard set of deviations (listed under vessels/craft)**

Operating industrial systems/equipment; **ISC and vessel only**
- System/equipment unavailable
- Poor quality products/service/operations
- **Standard set of deviations (listed under vessels/craft)**

Operating large caliber weapons; **ISC and vessel only**
- Inoperable weapons
- Inadvertent firing
- Firing live ammunition instead of blanks
- Firing at the wrong target/position
- **Standard set of deviations (listed under vessels/craft)**

Operating small caliber weapons and other weapons
- Inoperable weapons
- Inadvertent firing
- Inadvertent actuation of nonfirearm weapon (mace, stun gun, etc.)
- Firing live ammunition instead of blanks
- Firing at the wrong target/position
- **Standard set of deviations (listed under vessels/craft)**

Providing electronic systems services; **ISC and vessel only**

- Inadequate/no electronic systems service
- Electronic systems service quality problem
- **Standard set of deviations (listed under vessels/craft)**

Providing electrical power services; **ISC and vessel only**

- Inadequate/no electrical power service
- Incorrect electrical power frequency/voltage/phase
- **Standard set of deviations (listed under vessels/craft)**

Providing fueling services; **ISC and vessel only**

- Inadequate/no fueling services
- Fuel quality problem
- **Standard set of deviations (listed under vessels/craft)**

Providing ballasting; **vessel only**

- Inadequate/no ballasting
- **Standard set of deviations (listed under vessels/craft)**

Providing flood control services; **vessel only**

- Inadequate/no flood control
- Flood control quality problem
- **Standard set of deviations (listed under vessels/craft)**

Providing potable water services; **ISC and vessel only**

- Inadequate/no potable water
- Potable water quality problem
- **Standard set of deviations (listed under vessels/craft)**

Providing drainage services; **ISC and vessel only**

- Inadequate/no drainage system
- **Standard set of deviations (listed under vessels/craft)**

Providing heating/ventilation/air conditioning (HVAC) services; **ISC and vessel only**

- Inadequate/no HVAC
- **Standard set of deviations (listed under vessels/craft)**

Providing trash removal services; **ISC and vessel only**

- Inadequate/no trash removal
- **Standard set of deviations (listed under vessels/craft)**

Providing compressed air services; **ISC and vessel only**

- Inadequate/no compressed air
- Compressed air quality problem
- **Standard set of deviations (listed under vessels/craft)**

Providing compressed gas services; **ISC and vessel only**

- Inadequate/no compressed gases
- Compressed gas quality problem
- **Standard set of deviations (listed under vessels/craft)**

Providing sewage services; **ISC and vessel only**
- Inadequate/no sewage services
- Effluent quality problem
- **Standard set of deviations (listed under vessels/craft)**

Providing food services; **ISC and vessel only**
- Inadequate/no food services
- Food quality problem
- **Standard set of deviations (listed under vessels/craft)**

Providing berthing services; **ISC and vessel only**
- Inadequate/no berthing services
- Berthing quality problem
- **Standard set of deviations (listed under vessels/craft)**

Providing laundry services; **vessel only**
- Inadequate/no laundry services
- Laundry quality problem
- **Standard set of deviations (listed under vessels/craft)**

Providing steam services; **ISC and vessel only**
- Inadequate/no steam services
- Steam quality problem
- **Standard set of deviations (listed under vessels/craft)**

Providing medical services; **ISC and vessel only**
- Inadequate/no medical services
- Medical service quality problem
- **Standard set of deviations (listed under vessels/craft)**

Providing recreation services; **ISC and vessel only**
- Inadequate/no recreation services
- Recreation quality problem
- **Standard set of deviations (listed under vessels/craft)**

Providing administrative services
- Inadequate/no administrative services
- Administrative services quality problem
- **Standard set of deviations (listed under vessels/craft)**

Providing warehousing services; **ISC and vessel only**
- Inadequate/no warehousing service
- Warehousing quality problem
- **Standard set of deviations (listed under vessels/craft)**

Providing fire services; **ISC and vessel only**
- Inadequate/no fire services
- Fire service quality problem
- **Standard set of deviations (listed under vessels/craft)**

***Providing security services;* ISC and vessel only**
- Inadequate/no security services
- Security service quality problem
- **Standard set of deviations (listed under vessels/craft)**

Providing assessment/investigation/coordination services
- Inadequate/no assessment/investigation/coordination
- Assessment/investigation/coordination quality problem
- **Standard set of deviations (listed under vessels/craft)**

***Inspecting propulsion machinery and diesels;* MSO only**
- Inadequate/no inspection services
- Inspection service quality problem
- **Standard set of deviations (listed under vessels/craft)**

***Inspecting steering equipment;* MSO only**
- Inadequate/no inspection services
- Inspection service quality problem
- **Standard set of deviations (listed under vessels/craft)**

***Inspecting boilers and pressure vessels;* MSO only**
- Inadequate/no inspection services
- Inspection service quality problem
- **Standard set of deviations (listed under vessels/craft)**

***Inspecting auxiliary machinery/systems;* MSO only**
- Inadequate/no inspection services
- Inspection service quality problem
- **Standard set of deviations (listed under vessels/craft)**

***Inspecting electrical systems;* MSO only**
- Inadequate/no inspection services
- Inspection service quality problem
- **Standard set of deviations (listed under vessels/craft)**

***Inspecting fire protection equipment;* MSO only**
- Inadequate/no inspection services
- Inspection service quality problem
- **Standard set of deviations (listed under vessels/craft)**

***Inspecting lifesaving equipment;* MSO only**
- Inadequate/no inspection services
- Inspection service quality problem
- **Standard set of deviations (listed under vessels/craft)**

***Inspecting emergency equipment;* MSO only**
- Inadequate/no inspection services
- Inspection service quality problem
- **Standard set of deviations (listed under vessels/craft)**

Inspecting pollution prevention systems/equipment; **MSO only**
- Inadequate/no inspection services
- Inspection service quality problem
- **Standard set of deviations (listed under vessels/craft)**

Inspecting navigation equipment; **MSO only**
- Inadequate/no inspection services
- Inspection service quality problem
- **Standard set of deviations (listed under vessels/craft)**

Inspecting ground tackle; **MSO only**
- Inadequate/no inspection services
- Inspection service quality problem
- **Standard set of deviations (listed under vessels/craft)**

Inspecting deck equipment; **MSO only**
- Inadequate/no inspection services
- Inspection service quality problem
- **Standard set of deviations (listed under vessels/craft)**

Inspecting structures: hull and watertight integrity; **MSO only**
- Inadequate/no inspection services
- Inspection service quality problem
- **Standard set of deviations (listed under vessels/craft)**

Inspecting structures: hull — external; **MSO only**
- Inadequate/no inspection services
- Inspection service quality problem
- **Standard set of deviations (listed under vessels/craft)**

Inspecting structures: shore facilities; **MSO only**
- Inadequate/no inspection services
- Inspection service quality problem
- **Standard set of deviations (listed under vessels/craft)**

Inspecting accommodations; **MSO only**
- Inadequate/no inspection services
- Inspection service quality problem
- **Standard set of deviations (listed under vessels/craft)**

Inspecting cargo handling, storage, ballasting, and bunkering; **MSO only**
- Inadequate/no inspection services
- Inspection service quality problem
- **Standard set of deviations (listed under vessels/craft)**

Inspecting cargo pump rooms; **MSO only**
- Inadequate/no inspection services
- Inspection service quality problem
- **Standard set of deviations (listed under vessels/craft)**

3. Guide to Functions — 1/1/98

Function	Within Scope	Outside Scope
Operating vessels/ craft	Operating/maintaining engines Operating/maintaining thrusters Operating/maintaining steering systems Navigation and bridge functions	Operating/maintaining support systems for those systems listed to the left (addressed individually in subsequent functions)
Operating aircraft (in-flight and ground operations)	Operating/traveling in aircraft Operating tow tractors for moving aircraft on the ground Rolling helos into or out of hangars Maintaining helos Providing ground support during take-offs and landings	
Operating powered vehicles	Operating/maintaining/traveling in trucks, cars, mobile cranes, forklifts, etc.	Operating/maintaining/traveling in vessels or aircraft (addressed in analyses of aircraft or vessel operations) Lifting objects with a mobile crane or forktruck (addressed in analyses of lifting equipment operations)
Operating hand-operated moving equipment	Operating/maintaining dollies, carts, etc.	Operating/maintaining powered lifting equipment such as forklifts, cranes, and elevators (addressed in separate lifting equipment function) Rolling helos into/out of hangars (addressed in the ground transportation aspects of operating aircraft)
Operating lifting equipment	Operating/maintaining powered lifting equipment such as forklifts, cranes, elevators, etc. Operating/maintaining manual lifting gear such as "come-alongs," chain falls, and manual lifting tackle	Driving the mobile crane or forktruck around (addressed in analyses of powered vehicle operations)
Operating deck equipment	Operating/maintaining capstans, winches, etc.	Operating hand-held tools used on deck Operating lifting equipment (such as the small boat cranes and davits) or guns on deck (addressed in separate lifting and weapons functions)
Providing/maintaining structures (buildings, piers, vessels, craft, etc.)	Structural integrity of buildings, vessels, piers, etc. Maintaining structural elements of buildings, vessels, piers, etc.	Operating/maintaining support systems for the structures listed to the left (addressed individually in subsequent functions)

Function	Within Scope	Outside Scope
Operating industrial systems/equipment	Operating/maintaining equipment (such as welding equipment and drill presses) in maintenance shops Operating/maintaining portable equipment (such as welding equipment, cutting machines, etc.) at remote locations	Operating/maintaining support systems for buildings/vessels (addressed individually in other functions) Operating lifting equipment in conjunction with industrial systems/equipment (addressed in the lifting equipment function)
Operating large caliber weapons	Firing large caliber weapons Maintaining large caliber weapons Storing/transferring large caliber ammunition	Operating small caliber weapons (handguns, rifles, shotguns, mace, etc.) (addressed in the small caliber weapons function)
Operating small caliber weapons and other weapons	Operating/maintaining small caliber weapons and other weapons (handguns, rifles, shotguns, mace, etc.) Storing/transferring small caliber weapons and other weapons	Operating large caliber weapons (addressed in the large caliber weapons function)
Providing electronic services	Operating/maintaining radars Operating/maintaining radios and other communications systems (including satellite systems) Operating/maintaining guidance and positioning systems	Operating electrical power systems (addressed in the electrical power services function)
Providing electrical power services	Operating/maintaining generators Operating/maintaining distribution systems (cables, circuit breakers, etc.) Operating/maintaining shore ties	Operating electronic systems (addressed in the electronic services function) Using electrical power for various equipment such as industrial machines, hand tools, HVAC equipment, lifting equipment, etc. (addressed in the functions)
Providing fueling services	Operating/maintaining fuel tanks Operating/maintaining distribution piping Operating/maintaining equipment for replenishing fuel supplies	Using fuel associated with various equipment such as engines, generators, boilers, helos, industrial machines, vehicles, pumps, etc. (addressed in the functions associated with this equipment) Storage of small gasoline containers (addressed in the warehousing function)
Providing ballasting services	Operating/maintaining ballast tanks Operating/maintaining ballast piping system	Operating/maintaining support systems for buildings/vessels (addressed individually in other functions) Operating lifting equipment in conjunction with industrial systems/equipment (addressed in the lifting equipment function)

Function	Within Scope	Outside Scope
Providing flood control services	Operating/maintaining emergency pumping gear and flooding containment gear Providing/maintaining watertight compartments/doors	
Providing potable water	Operating/maintaining potable water Operating/maintaining desalination equipment Operating/maintaining distribution piping Operating/maintaining equipment for replenishing potable water supplies	Operating small caliber weapons (handguns, rifles, shotguns, mace, etc.) (addressed in the small caliber weapons function)
Providing drainage services	Operating/maintaining bilge systems Operating/maintaining deck, compartment, building, and parking lot drains	Use of emergency pumping gear for emergency flood control (addressed in flood control services)
Providing heating, ventilating, air conditioning services	Operating/maintaining HVAC systems	
Providing trash removal services	Operating/maintaining incinerators Storing/handling waste materials	Operating lifting equipment to transfer waste materials to shore (addressed in lifting equipment function)
Providing compressed air services	Operating/maintaining air compressors Operating/maintaining distribution piping	Use of compressed air cylinders (addressed in the compressed gas services function)
Providing compressed gas services	Storing/using/maintaining compressed gas cylinders	
Providing sewage services	Operating/maintaining the sewage tanks Operating/maintaining the sewage collection piping Operating/maintaining equipment for transferring sewage from the vessel	Use of potable water in food services applications, steam system, laundry services, sewage services, medical services, etc. (addressed in the various functions for these activities)
Providing food services	Food procurement function Food storage (including refrigerators and freezers) Food preparation and dispensing Operating/maintaining/cleaning galley equipment Sanitizing eating utensils, plates, pots, and pans	Food not served by crew (catered food, food consumed off site, food obtained/stored by individuals)

Function	Within Scope	Outside Scope
Providing berthing services	Providing/maintaining living quarters (including bunks) Providing/maintaining shower/ toilet facilities	
Providing laundry services	Operating/maintaining washers, dryers, etc.	
Providing steam services	Operating/maintaining boilers Operating/maintaining steam distribution piping	Providing potable water (addressed in potable water services function)
Providing medical services	Medical examinations/care Storing/dispensing medicine Storing/disposing of medical wastes	
Providing recreational services	Operating/maintaining recreational gear Performing recreational activities	
Providing administrative services	Operating/maintaining office equipment Performing office duties	
Providing warehousing services	Storing/distributing equipment and other materials	Storing/distributing fuel, potable water, ammunition, food, medical supplies, or trash (addressed in separate function related to use of those materials)
Providing fire services	Operating/maintaining fixed fire protection systems (halon, AFFF, water sprinklers) Operating/maintaining hose systems Operating/maintaining fire extinguishers (PKP, chemical, water) Operating/maintaining emergency portable fire pump/hose systems	
Providing security services	Standing security-related watches Dealing with security issues (confronting trespassers, subduing assailants, etc.)	Using small caliber weapons and other weapons (addressed in the small weapons function)
Providing assessment/ investigation/ coordination services	Standing watches Performing rounds Conducting specific audits, examinations, and evaluations	
Inspecting . . . (specify item to be inspected); MSO inspection functions	Conducting specific audits, inspections, and examinations of systems, equipment, structures, etc.	

4. Guide to Deviations — 1/1/98

Deviation	Purpose	Examples of Issues Related to Deviation [shown as Deviation (*function*)]
{Function} unavailable	Explores potential mishaps resulting from a loss of functionality (complete or partially degraded capability)	Vessel/craft unavailable (*operating vessels/craft*): Loss of mission capability Inadequate/no flood control (*providing flood control services*): Flooding of vessel compartment
{Function} quality problem	Explores potential mishaps resulting from upsets in delivery of a function (i.e., failures to meet specific performance criteria, given that the function is occurring)	Incorrect position/direction/speed (*operating vessels/craft*): Collision or grounding of vessel Potable water quality problem (*providing potable water services*): Exposure of crew to biological hazards Firing live ammunition instead of blanks (*operating large caliber weapons*): Potential personnel/ public injury
Physical hazards	Explores how personnel could be injured or equipment damaged in the routine performance of the function	Physical hazards (*operating deck equipment*): Physical injury caused by a hand caught in a winch Physical hazards (*providing food services*): Physical injury caused by cuts from sharp knives and food preparation equipment
Toxic/corrosive/ reactive materials exposure	Explores how personnel could be injured or equipment damaged from exposure to hazardous materials during routine performance of the function	Toxic/corrosive/reactive materials exposure (*providing laundry services*): Personnel exposure caused by splashing of bleach into a crew member's eyes Toxic/corrosive/reactive materials exposure (*providing steam services*): Personnel exposure resulting from handling of insulation containing asbestos during maintenance of steam pipes

Deviation	Purpose	Examples of Issues Related to Deviation [shown as Deviation (*function*)]
Fire/explosion	Explores how personnel could be injured or equipment damaged from a fire/explosion during routine performance of the function	Fire/explosion (*providing fueling services*): Fire caused by ignition of fuel spill that occurs during fueling of a vessel Fire/explosion (*providing electrical power services*): Explosion caused by ignition of hydrogen that evolves from battery charging
Asphyxiating environment exposure	Explores how personnel could be placed in an asphyxiating environment during routine performance of the function	Asphyxiating environment exposure (*providing HVAC services*): Asphyxiation of a crew member in a space with limited natural ventilation Asphyxiating environment exposure (*providing fire services*): Asphyxiation of a crew member in a space protected by a halon system
Electrical hazards exposure	Explores how personnel could be injured or equipment damaged from electricity during routine performance of the function	Electrical hazards exposure (*providing electrical power services*): Person electrocuted from contact with a high voltage circuit breaker Electrical hazards exposure (*providing electronic services*): Sensitive equipment damage by a power supply surge Electrical hazards exposure (*operating industrial equipment/ machines*): Person electrocuted because of an internal short in a motor that was not well-grounded
High pressure materials exposure	Explores how personnel could be injured or equipment damaged from a release of high pressure materials during routine performance of the function	High pressure materials exposure (*providing compressed gas services*): Person injured or equipment damaged by escaping gas from a compressed gas cylinder failure

Deviation	Purpose	Examples of Issues Related to Deviation [shown as Deviation (*function*)]
High noise exposure	Explores how personnel could be injured in a high noise environment during routine performance of the function	High noise exposure (*operating vessels/craft*): Hearing damage for person stationed in compartment adjacent to engine room while the vessel is underway High noise exposure (*operating large caliber weapons*): Hearing damage from person not wearing ear protection on deck when weapons are being fired
Excessive vibration exposure	Explores how personnel could be injured or equipment damaged from excessive vibration during routine performance of the function	Excessive vibration exposure (*operating vessels/craft*): Fatigue damage to equipment adjacent to the engines caused by vibration from the engines
Radiation exposure	Explores how personnel could be injured or equipment damaged from radiation during routine performance of the function	Radiation exposure (*providing electronic systems services*): Exposure of maintenance technician to energized radar while working aloft
Biological hazards exposure	Explores how personnel could be injured from biological organisms during routine performance of the function	Biological hazards exposure (*providing food services*): Exposure of crew to inadequately cooked meat Biological hazards exposure (*providing sewage services*): Exposure of crew member to organisms while maintaining sewage system
Hot/cold environments exposure	Explores how personnel could be injured or equipment damaged from hot/cold environments during routine performance of the function	Hot/cold environments exposure (*operating deck equipment*): Frostbite for crew member while working on deck in cold weather
Hot/cold surfaces/ materials exposure	Explores how personnel could be injured or equipment damaged from hot/cold surfaces/materials during routine performance of the function	Hot/cold surfaces/materials exposure (*providing steam services*): Thermal burns for crew member caused by a failed steam line

Vessel operations/evolutions and function matrix

Vessel Function	Working aids to navigation	Towing	Boarding	Damage control – fire	Damage control – flood	Helicopter operations	Fueling – pier side	Fueling – underway replenishment	Small boat launch/ recovery – from vessel	Small boat launch/ recovery – from land	Anchored/moored/ stored	Vessel leaving/ returning	Vessel in transit/ restricted waters	Launch/recover swimmers/divers	Not operation/ evolution specific (including open water maneuvering)
Operating vessels/craft	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Operating aircraft (in-flight and ground operations)						✓									
Operating hand-operated moving equipment (dollies, carts, etc.)											✓				✓
Operating lifting equipment	✓								✓		✓				✓
Operating deck equipment (excluding small boat davit/crane)	✓	✓					✓	✓			✓	✓			✓
Providing/maintaining structures (buildings, piers, vessels, craft)															✓
Operating industrial systems/ equipment															✓
Operating large caliber weapons			✓												✓
Operating small caliber weapons and other weapons			✓												✓
Providing electronic systems services													✓		✓
Providing electrical power services						✓					✓				✓
Providing fueling services						✓					✓				✓
Providing ballasting services															✓
Providing flood control services					✓										
Providing potable water services											✓				✓
Providing drainage services											✓				✓

Vessel Function	Vessel Operation/Evolution: Working aids to navigation	Towing	Boarding	Damage control – fire	Damage control – flood	Helicopter operations	Fueling – pier side	Fueling – underway replenishment	Small boat launch/ recovery – from vessel	Small boat launch/ recovery – from land	Anchored/moored/ stored	Vessel leaving/ returning	Vessel in transit/ restricted waters	Launch/recover swimmers/divers	Not operation/ evolution specific (including open water maneuvering)
Providing heating/ventilating/air conditioning (HVAC) services															✓
Providing trash removal services											✓				✓
Providing compressed air services															✓
Providing compressed gas services															✓
Providing sewage services											✓				✓
Providing food services															✓
Providing berthing services															✓
Providing laundry services															✓
Providing steam services															✓
Providing medical services															✓
Providing recreation services															✓
Providing administrative services															✓
Providing warehousing services											✓				✓
Providing fire services				✓											
Providing security services											✓				✓
Providing assessment/investigation/ coordination services			✓								✓				✓

ISC operations/evolutions and function matrix

ISC Function	ISC Operation/Evolution		
	Pier services	Industrial services	Base services
Operating vessels/craft			✓
Operating aircraft (in-flight and ground operations)			✓
Operating powered vehicles (trucks, cars, mobile cranes, forklifts, etc.)	✓	✓	✓
Operating hand-operated moving equipment (dollies, carts, etc.)	✓	✓	✓
Operating lifting equipment	✓	✓	✓
Providing/maintaining structures (buildings, piers, vessels, craft)	✓	✓	✓
Operating industrial systems/ equipment	✓	✓	✓
Operating large caliber weapons	✓		✓
Operating small caliber weapons and other weapons	✓		✓
Providing electronic systems services		✓	✓
Providing electrical power services	✓	✓	✓
Providing fueling services	✓	✓	✓
Providing potable water services	✓	✓	✓
Providing drainage services	✓	✓	✓
Providing heating/ventilating/air conditioning (HVAC) services		✓	✓
Providing trash removal services	✓	✓	✓
Providing compressed air services	✓	✓	✓
Providing compressed gas services	✓	✓	✓
Providing sewage services	✓	✓	✓
Providing food services			✓
Providing berthing services			✓

ISC Function	ISC Operation/Evolution		
	Pier services	Industrial services	Base services
Providing steam services	✓	✓	✓
Providing medical services			✓
Providing recreation services			✓
Providing administrative services		✓	✓
Providing warehousing services		✓	✓
Providing fire services			✓
Providing security services			✓
Providing assessment/investigation/ coordination services			✓

MSO operations/evolutions and function matrix

MSO Function	MSO Operation/Evolution							
	Letter of Compliance inspections	Overseas inspections	Deep draft inspections – dry dock	Pollution response	Barge inspections	Container inspections	Waterfront facility inspections	Port security operations
Operating vessels/craft	✓			✓	✓	✓	✓	✓
Operating aircraft (in-flight and ground operations)	✓	✓	✓	✓				✓
Operating powered vehicles (trucks, cars, mobile cranes, forklifts, etc.)	✓	✓	✓	✓	✓	✓	✓	✓
Operating hand-operated moving equipment (dollies, carts, etc.)				✓				✓
Operating lifting equipment				✓				✓
Providing administrative services	✓	✓	✓	✓	✓	✓	✓	✓
Providing assessment/investigation/ coordination services				✓		✓	✓	✓
Inspecting propulsion machinery and diesels	✓	✓	✓					
Inspecting steering equipment	✓	✓	✓		✓			
Inspecting boilers and pressure vessels		✓	✓					
Inspecting auxiliary machinery/ systems	✓	✓	✓		✓			
Inspecting electrical systems	✓	✓	✓		✓			
Inspecting fire protection equipment	✓	✓	✓		✓			
Inspecting lifesaving equipment	✓	✓	✓		✓			
Inspecting emergency equipment	✓	✓	✓		✓			
Inspecting pollution prevention systems/equipment	✓	✓	✓		✓			
Inspecting navigation equipment	✓	✓	✓					
Inspecting ground tackle	✓	✓	✓		✓			

MSO Function	MSO Operation/Evolution							
	Letter of Compliance inspections	Overseas Inspections	Deep draft Inspections – dry dock	Pollution response	Barge Inspections	Container Inspections	Waterfront facility inspections	Port security operations
Inspecting deck equipment	✓	✓	✓		✓			
Inspecting structures: hull and watertight integrity		✓	✓		✓			
Inspecting structures: hull – external	✓	✓	✓		✓			
Inspecting structures: shore facilities								
Inspecting accommodations	✓	✓						
Inspecting cargo handling, storage, ballasting, and bunkering	✓	✓	✓		✓			
Inspecting cargo pump rooms	✓	✓	✓					